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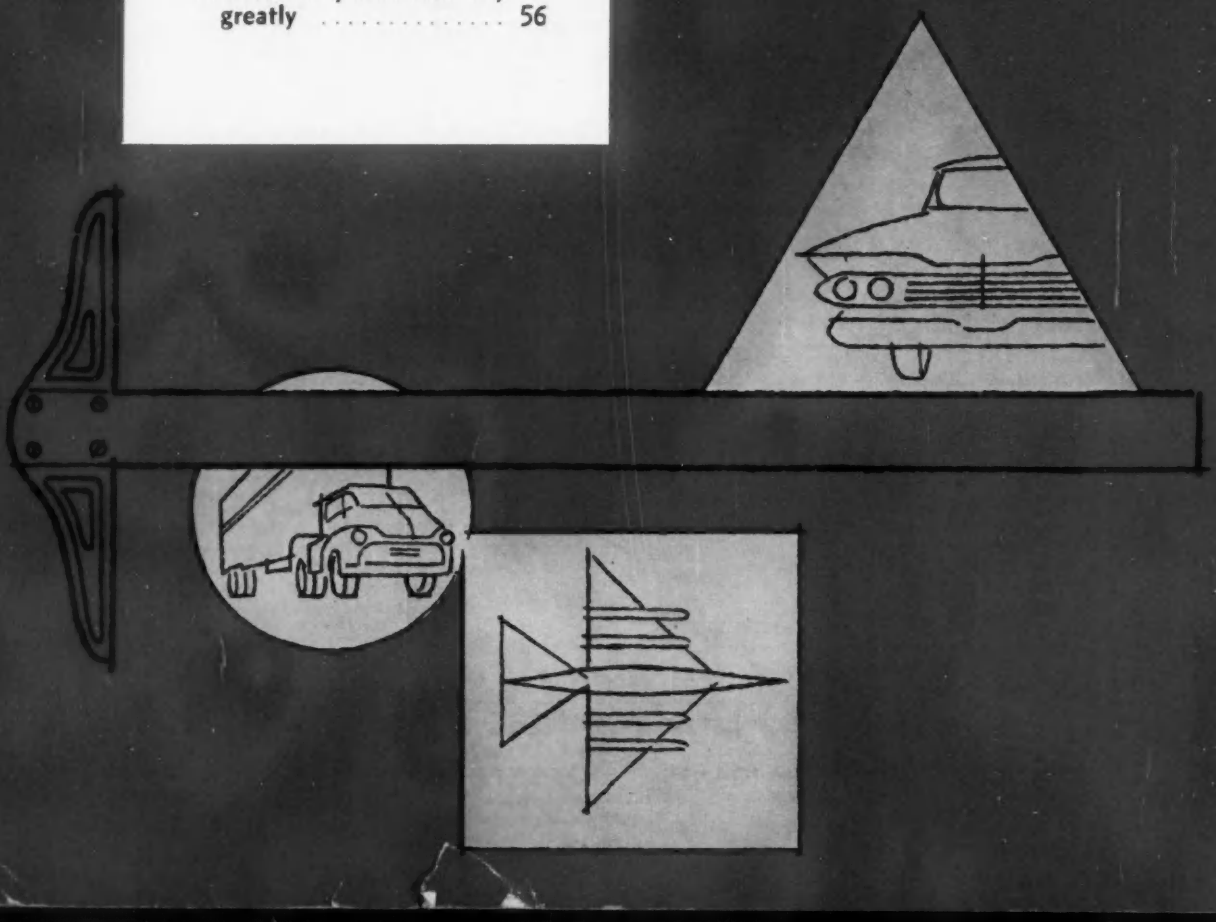

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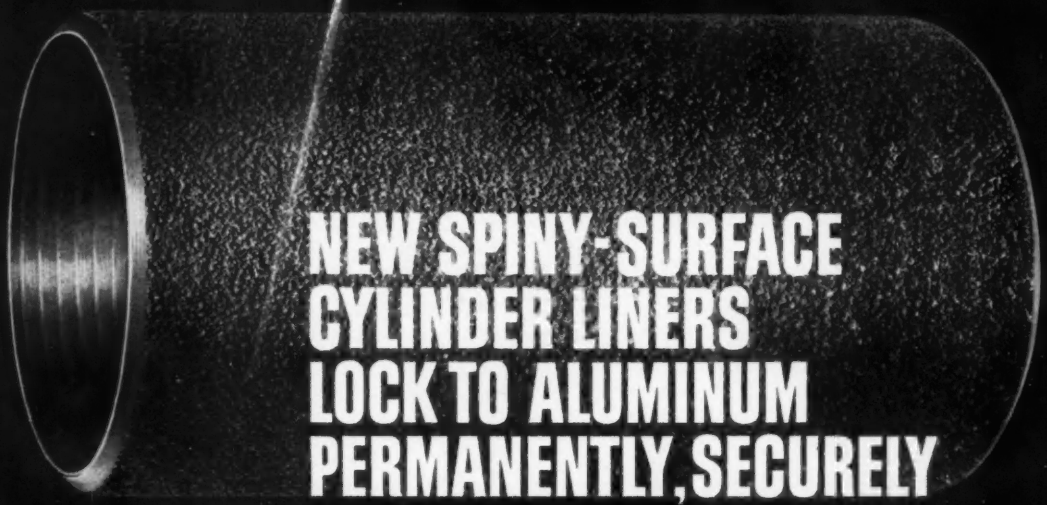

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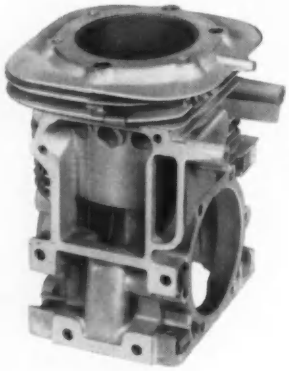

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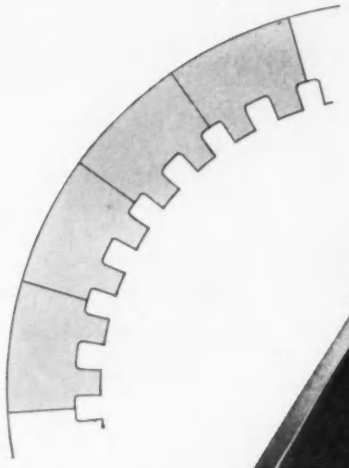

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Development of Steep Gradient Aircraft for Short Haul Transportation, L. L. DOUGLAS. Paper No. 266F. Examination of operating cost of five helicopters and VTOL aircraft in comparison with fixed wing transport; projections of current cost experience; analysis shows that at range of 100 mi helicopter has direct operating cost of twice that of fixed wing aircraft; potential of helicopters and VTOL wing aircraft approaches cost of fixed wing aircraft for longer ranges, with lower operating costs of helicopter for shorter ranges.

Fundamental Materials Considerations in Liquid Metal Heat Exchangers, B. F. BROWN, S. W. STRAUSS. Paper No. 280D. Materials principles developed in studies by U. S. Naval Research Laboratories and others, relating to heat transfer systems applicable to nuclear propulsion plants in hydrofoils or in submarinelike vessels, in recuperators for aircraft turboprop engines, or employed for boiling and condensing liquid metal cycles for turning turbogenerator power plants in space vehicles, etc.; properties of liquid metals; containment problem; phenomenon of mass transfer.

Direct Energy Conversion, J. T. HAYWARD. Paper No. 297B. U. S. Navy's power system requirements for air and space flight vehicles, remote power, portable power and unattended devices, and shipboard power for propulsion and auxiliary uses; possible combinations of energy source and conversion processes for these are examined within program on direct conversion of source energy to usable electrical energy; major attention is paid to photovoltaic, thermoelectric, thermionic emission, chemical in fuel cells, and magnetohydrodynamics; common characteristics.

Forecasts for Flight Vehicle Power, G. W. SHERMAN. Paper No. 297C. Forecasts of power requirements are derived for various concepts of flight vehicles for future Air Force missions; synthesis of forecasts of 1962 and 1966 requirements for boosters, boost glide and glide re-entry vehicles, unmanned air vehicles, earth satellites, lunar and interplanetary vehicles; synthesis of forecasts of 1962 and 1966 areas of optimum application of energy conversion methods; research program designed to supply technology for power subsystems development.

Mechanization of Minimum-Energy Automatic Lunar Soft-Landing Systems, C. M. MEARS, R. L. PETERSON. Paper No. 302A. Nondimensional parameters are developed and plotted for use in rapid analysis of soft-landing system concepts for space vehicles; systems which automatically control and reduce vehicle energy remaining after main-stage retrothrust, to zero at landing surface; mechanizations of some systems are presented and compared with optimum system in terms of energy consumption and ability to tolerate wide ranges of initial vehicle velocities and positions.

Human Factors of Lunar Logistics Mission, R. O. LOWREY, J. T. RAY. Paper No. 302C. Paper is based on "Project Moonbeam" — 10,000-lb payload lunar vehicle, feasibility of which is foreseen for 1970; tasks for which crew members may be considered are: monitoring and controlling, failure detection and isolation, and system repair; physiological and psychological factors; areas requiring greatest advancement in interim time period are radiation, meteoroids, zero gravity, and emergency escape. 25 refs.

Lunar Exploration Systems, N. W. O'ROURKE. Paper No. 302D. Preliminary results of system study of NOVA space system carried out by Convair Div. of General Dynamics Corp.; method of approach and factors involved in program planning, and design of vehicle and systems used for manned exploration; effects of major

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systems variables on gross weight; effects on cost; effectiveness, reliability, and safety considerations; example of 5-stage chemical vehicle, in which first two stages consist of cluster of four Saturn-type boosters.

Long Time Exposure of Hydraulic Controls in Space Environments, A. B. BILLET. Paper No. 302E. Requirements of environments under which control equipment such as retrorocket and landing strut controls of soft landing lunar vehicle operate; field operation study was provided by inspection of hydraulic components from B-24 aircraft that lay in North African Libyan Desert for 17 yr; in comparing combined environment results with this equipment, direct correlation was found; equipment showed no detrimental effects, with piston pumps meeting requirements of new unit following exposures.

Ground Based Microwave System for Spot Landing of Space Vehicles, M. I. BEERS, C. C. STOTZ, R. A. WALLACE. Paper No. 302F. Problems associated with return of such vehicles as low lift-to-drag glider Dyna Soar; flight profile for return to earth consists of orbiting earth, firing retro-rockets to initiate re-entry, and landing at designated spot; guidance problems and requirements; details of Microwave Aerospace Navigation (MAN) System for guiding vehicle throughout re-entry, approach and landing; ground control equipment at landing site and data transponder equipment in vehicle.

Cost of Lunar Travel, M. W. HUNTER. Paper No. 302H. Rough cost estimates of lunar transportation systems involving relatively conventional rockets; typical chemical fuel costs expected to be of order of 2¢/lb for liquid oxygen, and 25¢/lb for liquid hydrogen; direct-operating costs, launch and development costs; cost of lunar transportation by conventional chemical propulsion seems to be extremely high, but can be substantially improved by going to high-energy recoverable systems and even more by nuclear recoverable rockets.

Transportation System to Establish Manned Lunar Outpost, F. L. WILLIAMS, H. O. RUPPE, R. G. W. REICHERT. Paper No. 302J. Comparison of systems possible by late 1960's or early 1970's; data on following possible types: solid propelled vehicle, LO_2/RP and LO_2/LH_2 propelled vehicle; all nuclear type, vehicle using LO_2/RP first stage and LO_2/LH_2 upper stages, design using LO_2/LH_2 first stage and nuclear second, third, and fourth stages and LO_2LH_2 landing stage; cost of transporting man and material to and from moon.

Lithium Hydrogen Regenerative Fuel Cell System, D. R. SNOKE, J. M. FUSCOE. Paper No. 308D. Development of system, which fulfills requirements for space and ground applications, and by Tapco Group of Thompson Ramo Wooldridge, Inc.; system is 500 w, 28 v d-c regenerative fuel cell, capable of operating in gravitationless environment for periods for 1 yr; regenerator and separation; auxiliary components; systems optimization summary; characteristics include open circuit voltage 0.6 v, operating voltage 0.45 v, current density of operating voltage 200 amp/sq ft.

The Economics of a Short-Range Commercial Jet Transport. E. F. Burton

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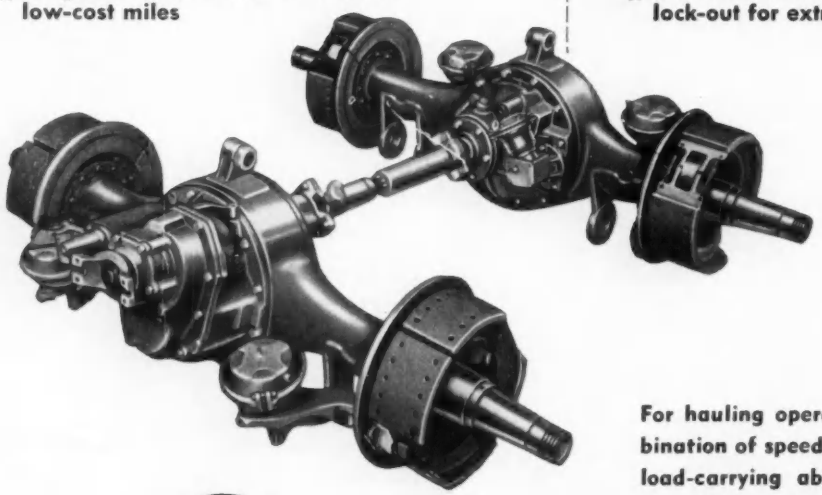

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MANUFACTURING COMPANY

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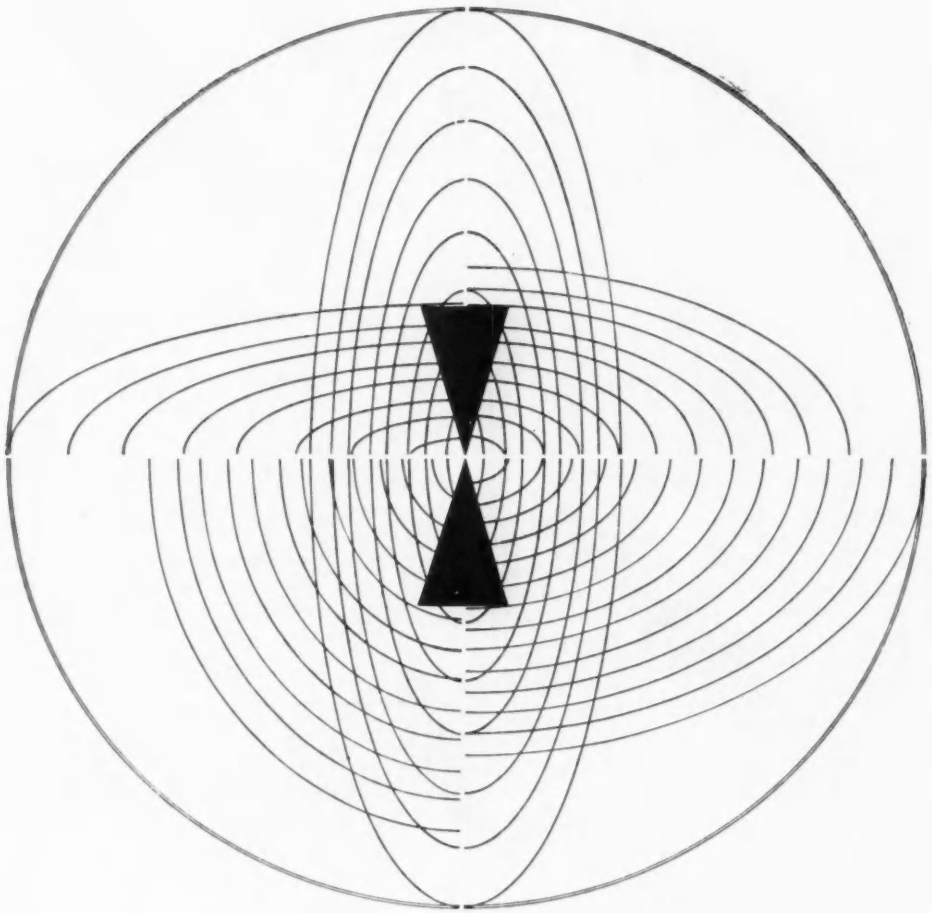


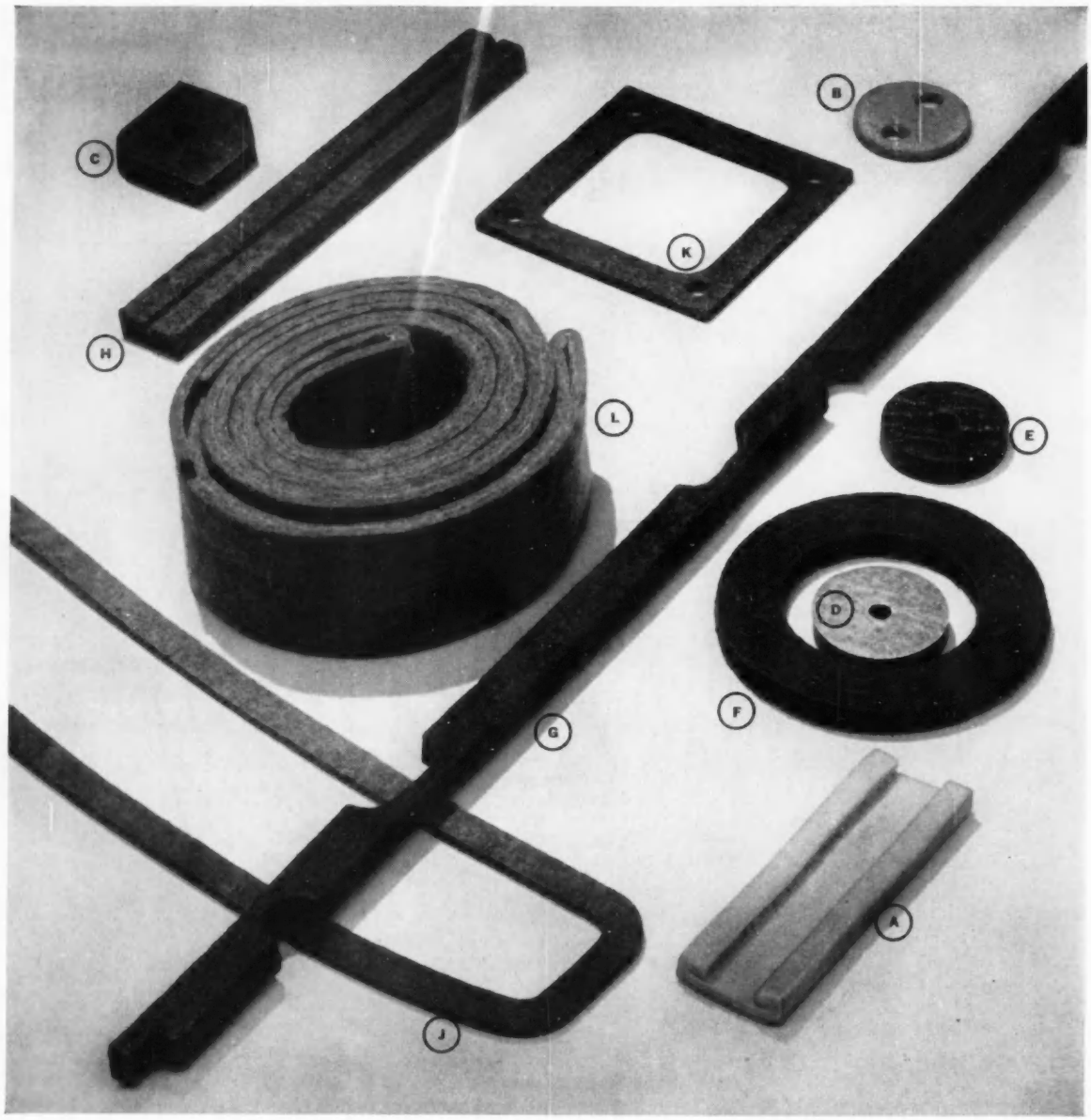
Precision

has at all times been the fundamental condition for the manufacture of Goetze products.

In the last twelve month, among other articles, we have supplied more than 60 million piston rings to the European manufactures of engines, jets and gears.

At present more than 3,700 men are employed in our works.

GOETZEWERKE FRIEDRICH GOETZE AG · BURSCHEID BEI KÖLN



DO YOU need a versatile engineering material to repel water, stop rust, stop dust? Or a material that is flameproof or mildewproof . . . resistant to sound, odor, friction, acid, alkali, oil, heat, cold or wear? Think of Western Felt.

Western Felt can supply over 92 different **TREATED FELTS** to meet your specifications and give special protection long after other materials break down.

A—Flameproofed felt rattleproofs fire extinguishers.
B—Mildewproofed felt repels water while lubricating air conditioners.
C—Polyethylene-treated felt around car clutch arm stops dust, motor noise, odor.
D—Polypropylene-treated felt around accelerator rod resists friction, acids, alkalies, organic solvents.
E—Resin-coated felt around clutch arm resists oil and water, seals off driving compartment.
F—Wax-impregnated felt resists water—makes an extra-firm steering-column seal.
G—Waterproofed felt bars water and dust from gear box.
H—Adhesive-coated felt quickly affixed, lubricates porcelain shoe on clothes dryer.
J—Wax-impregnated felt repels water, prevents corrosion, seals junction box on truck trailer.
K—Hycar-impregnated felt resists abrasion and wear—seals lint trap on clothes dryer.
L—Teflon-coated, latex-impregnated felt around clothes dryer drum reduces friction, motor load—withstands heat. Tensile strength extends dryer life.

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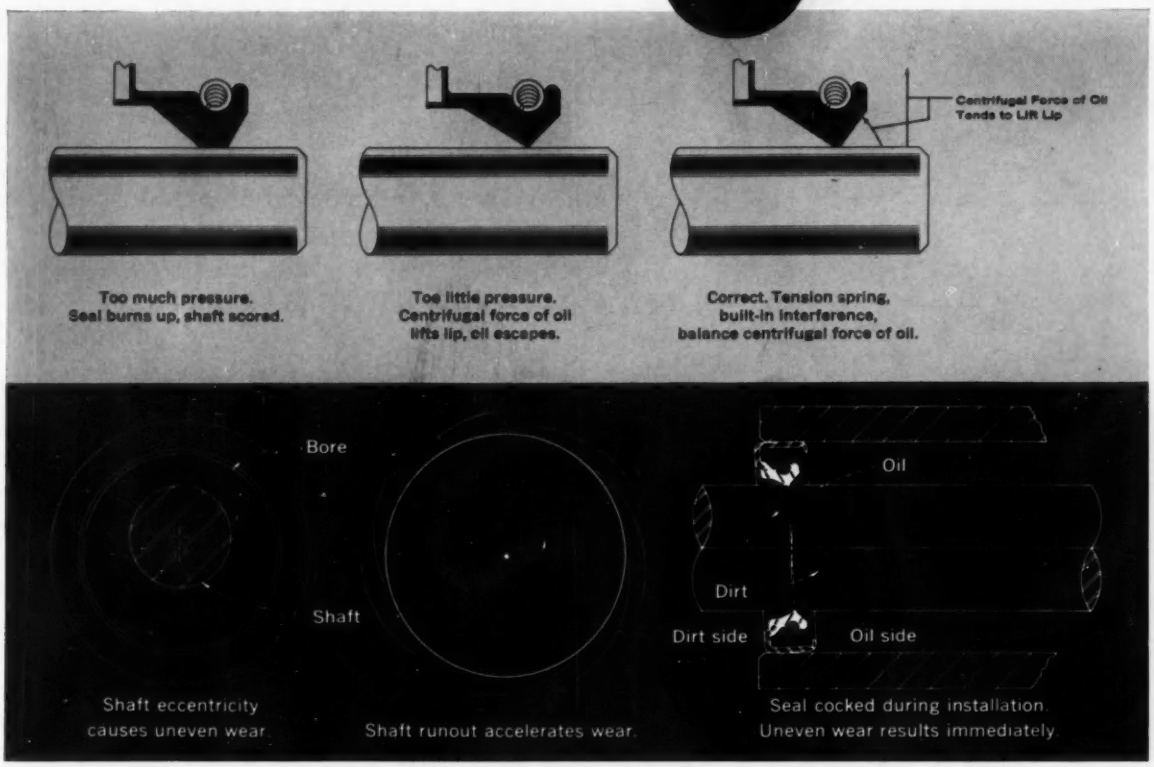
MANUFACTURERS AND CUTTERS OF WOOL FELTS AND SYNTHETIC RUBBER

Lip pressure...too much or too little, and you've a leaker for sure!


Centrifugal Force of Oil Tends to Lift Lip
Too much pressure. Seal burns up, shaft scored.
Too little pressure. Centrifugal force of oil lifts lip, oil escapes.
Correct. Tension spring, built-in interference, balance centrifugal force of oil.
Bore
Shaft
Shaft eccentricity causes uneven wear.
Shaft runout accelerates wear.
Oil
Dirt
Dirt side
Oil side
Seal cocked during installation. Uneven wear results immediately.

Ideal sealing conditions are (1) shaft in bore center, (2) no runout, (3) seal not cocked, (4) seal concentric, (5) bore round and smooth, (6) shaft round and properly finished, (7) seal proper size.

Meeting these conditions is complicated, frequently requires special seal design or the specialized knowledge of National Seal engineers.

Sealing problems should be anticipated and answered on the board, not in production. Why not call your National Seal engineer now about your current project. He's in the Yellow Pages, under Oil Seals or O-Rings.

NATIONAL SEAL
Division, Federal-Mogul-Bower Bearings, Inc.
GENERAL OFFICES: Redwood City, California
PLANTS: Van Wert, Ohio; Redwood City and Downey, California

6060

CELANESE POLYMER COMPANY

announces a new engineering material

CELCON®

ACETAL COPOLYMER

Celcon is an entirely new Celanese plastic offering advantages over metals and other fabricating materials in many applications. Celcon has a unique combination of properties, including high structural strength over a broad temperature range, excellent moldability, resistance to corrosion and creep, fine color and surface. Best of all, in extensive laboratory and field tests, Celcon performed at a high level with long-range stability. Celcon promises to answer the need for a material in which you can design with greater confidence!

Celanese POLYMER

Product of Radically New Molecular Architecture

Celcon is a result of extensive Celanese experience in polymer chemistry. It makes possible new concepts of material use; it is a new design medium.

Celanese maintains strict control of Celcon production, from raw materials to finished polymer. Celanese is the world's largest producer of trioxane—basic monomer of Celcon production. Celcon is now available for your evaluation in developmental quantities on a restricted basis.

Celcon Meets the Challenge of the Materials Age

- Combines low cost with high strength and rigidity
- Easily fabricated—injection molded, extruded, machined
- Resistant to a wide range of chemicals
- Resistant to high temperatures
- High creep resistance even at elevated temperatures
- Excellent colorability
- Unusual versatility in molding
- Broad molding range

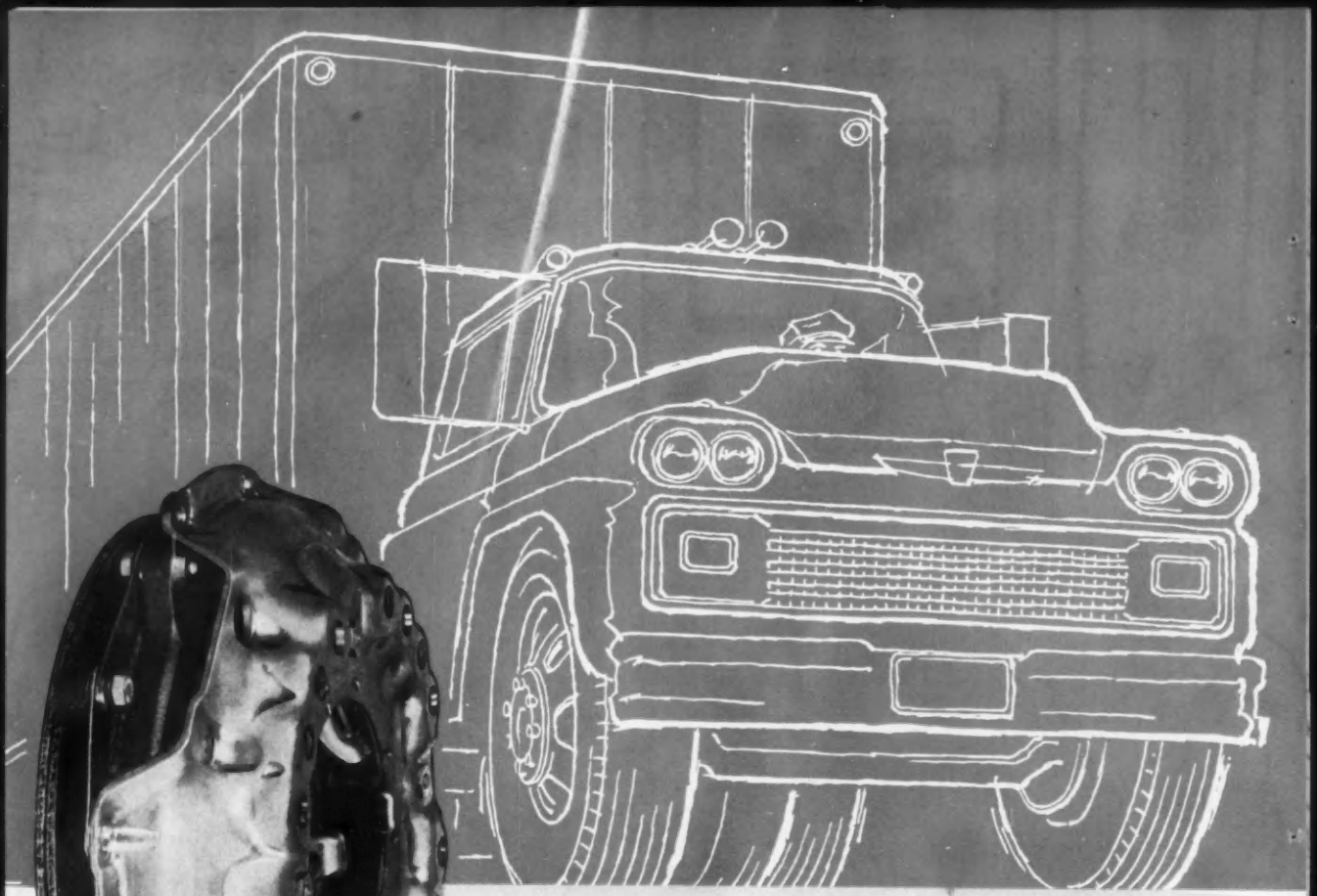
Uses as Varied As Industry Itself

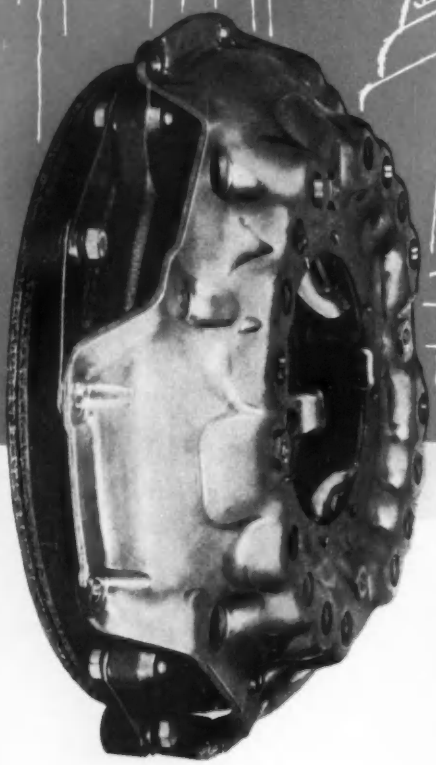
Celcon, as a fabrication material and styling medium offers many advantages over metals and other materials for a wide variety of applications, such as timing gears, door handles, pipe and plumbing, sporting goods, automotive parts, electrical appliance parts, machinery housings and components, pump parts and impellers. But these are only an *indication* of where this versatile new engineering material can be used to both product and cost advantage.

Celanese® Celcon®

For complete details, please write, outlining your application, to:
Celanese Polymer Company, Dept. P1735, 744 Broad Street, Newark 2, N. J.

Celanese Polymer Company is a Division of Celanese Corporation of America





New BORG & BECK 2-Plate "Strap-Drive" Clutches

PACK MORE MUSCLE...WITHOUT ADDED SIZE

Trucks pay out on the road, not in the shop. So it's asking for trouble when a truck engine is too big for its clutch.

To help keep 'em rolling, Borg & Beck has developed a new line of 2-plate clutches with up to 40% greater load capacity . . . yet without any increase in nominal size.

Rated at 500 ft.-lbs. torque capacity, this new Borg & Beck Type 13E2 has 12⅞" O.D. x 7¼" I.D. facings . . . non-cushion rigid or flexible center drive plate . . . space for 16 heat treated coil springs of total load to suit type of service . . . "strap drive" for positive, trouble-free plate separation.

And like all Borg & Beck clutches, Type 13E2 is built to Borg & Beck's pace-setting standards for quality, performance and value. Consult our engineers for details.

BORG & BECK CLUTCH THE STANDARD

Reg. U.S. Pat. Off.

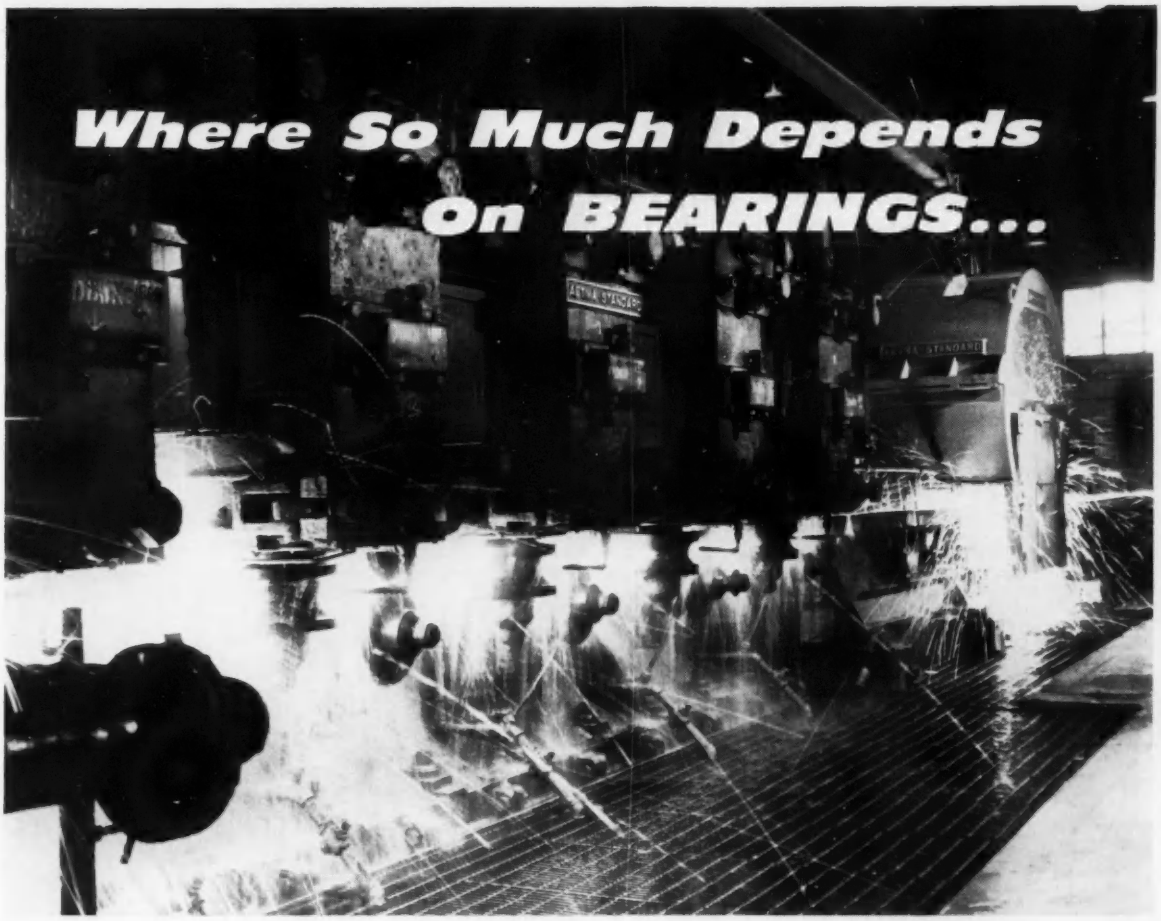
BORG & BECK B-W DIVISION BORG-WARNER

BORG & BECK®

THE AUTOMOTIVE STANDARD FOR MORE THAN 40 YEARS

BORG & BECK DIVISION, BORG-WARNER CORPORATION, CHICAGO 38, ILLINOIS

Export Sales: Borg-Warner International, 36 S. Wabash, Chicago 3



Rollway Bearing - equipped pipe - forming and welding stands at J & L Aliquippa Works. Rollways are also used in other equipment at Aliquippa, including cranes, crane hooks and mill motors.

It Pays to Depend On ROLLWAY

The addition of two Continuous Weld Pipe Mills has increased Jones and Laughlin's rated monthly capacity of welded pipe to 35,000 net tons. The mills have operated since 1957.

Both mills are Rollway Bearing-equipped, as are J & L's Stretch Reducing Mill and Electric Weld Tube Mill, installed at the same time.

Operations like these *demand* component reliability. Dependable Rollway Bearings regularly provide it. You can choose from a complete selection of sizes and types with maximum capacities. Consult Rollway's nearest Engineering Office to select the bearing just right for your job. Or start by writing for Product Line Catalog 559. Rollway Bearing Co., Inc., Syracuse, N.Y.

You can depend on

ROLLWAY®
BEARINGS
Radial and Thrust Cylindrical Roller Bearings

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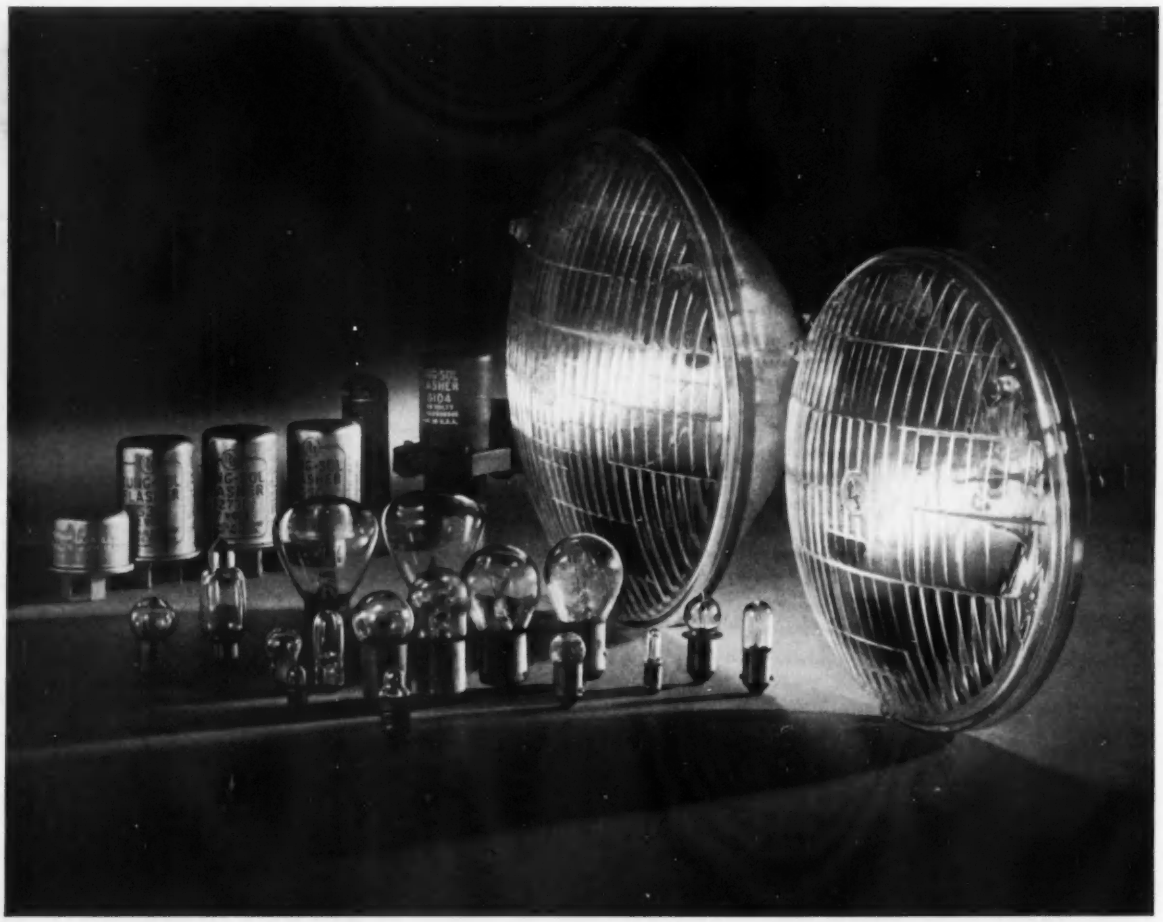
Tung-Sol has achieved remarkable results in meeting the ever higher quality demands of the automobile industry while lowering the cost of Tung-Sol products



TUNG-SOL®

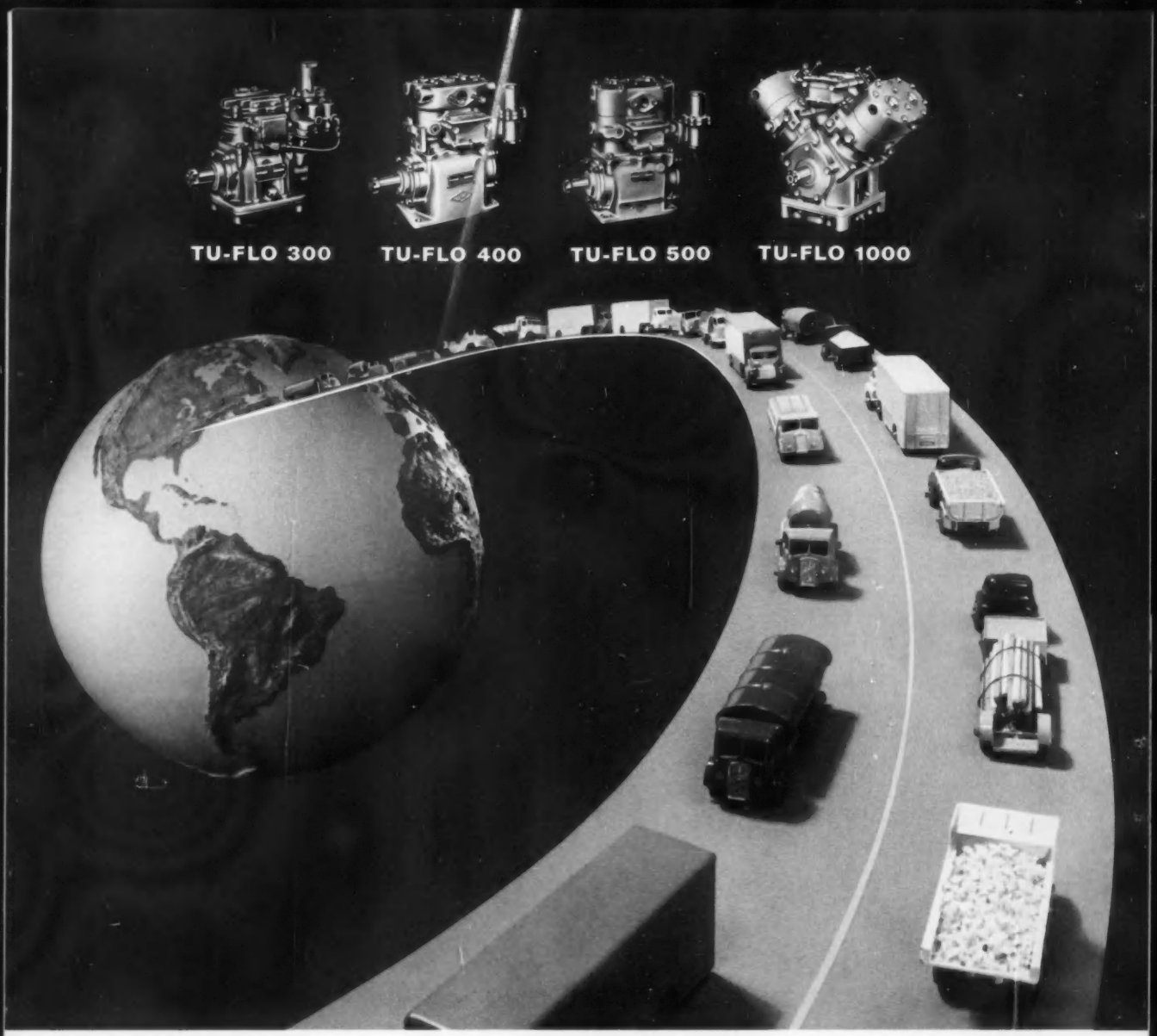
TUNG-SOL ELECTRIC INC., NEWARK 4, N. J./TWX: NK193

HEADLAMPS • MINIATURE LAMPS • FLASHERS

THE FACTS OF LIFE ABOUT AIR BRAKES. Many a perspiring parent has used the birds-and-bees routine to explain the facts of life. In case you've missed the facts of life about air brakes, we'd like to say that there's a real difference between makes. Quality differs. Performance differs. The companies that make them differ. That's why we ask you to consider all the facts of life about air brakes. When you do, we're confident you'll select Bendix-Westinghouse. Reason: Since 1923, we've manufactured to a quality and performance standard—not just to a price. This policy is your assurance you will continue to get most-value-per-dollar by specifying Bendix-Westinghouse Air Brakes—the product and name you can trust.

SPECIFY COMPLETE AIR BRAKE SYSTEMS BY *Bendix-Westinghouse*

BENDIX-WESTINGHOUSE AIR BRAKES®



Dependable in every kind of transport operation . . .

BENDIX-WESTINGHOUSE TU-FLO COMPRESSORS

Bendix-Westinghouse compressors have met the highest performance standards in hundreds of billions of miles of service on all kinds of commercial vehicles, over all kinds of roads, and in every conceivable weather. Over the years, more than 2¼ million of these dependable units have provided consistently efficient braking power.

A TU-FLO COMPRESSOR TO MEET EVERY NEED: ● TU-FLO 300 for lightweight trucks and school buses. ● TU-FLO 400 most widely used by over-the-highway haulers. ● TU-FLO 500 for city and interstate buses, off-the-road vehicles, and heavy-duty trucks. ● TU-FLO 1000, new high-capacity unit, for stationary and mobile air supply systems.

INTERCHANGEABILITY AN IMPORTANT SYSTEM ADVANTAGE: If your fleet includes many different makes of vehicles, you'll enjoy maximum air brake parts interchangeability if you specify Bendix-Westinghouse—because Bendix-Westinghouse is available as standard or optional equipment for every make of tractor and trailer on the market. Think what this interchangeability can mean to you in easier servicing and simplified parts inventory and bookkeeping.

So, for the best in air brake dependability, always specify Bendix-Westinghouse.

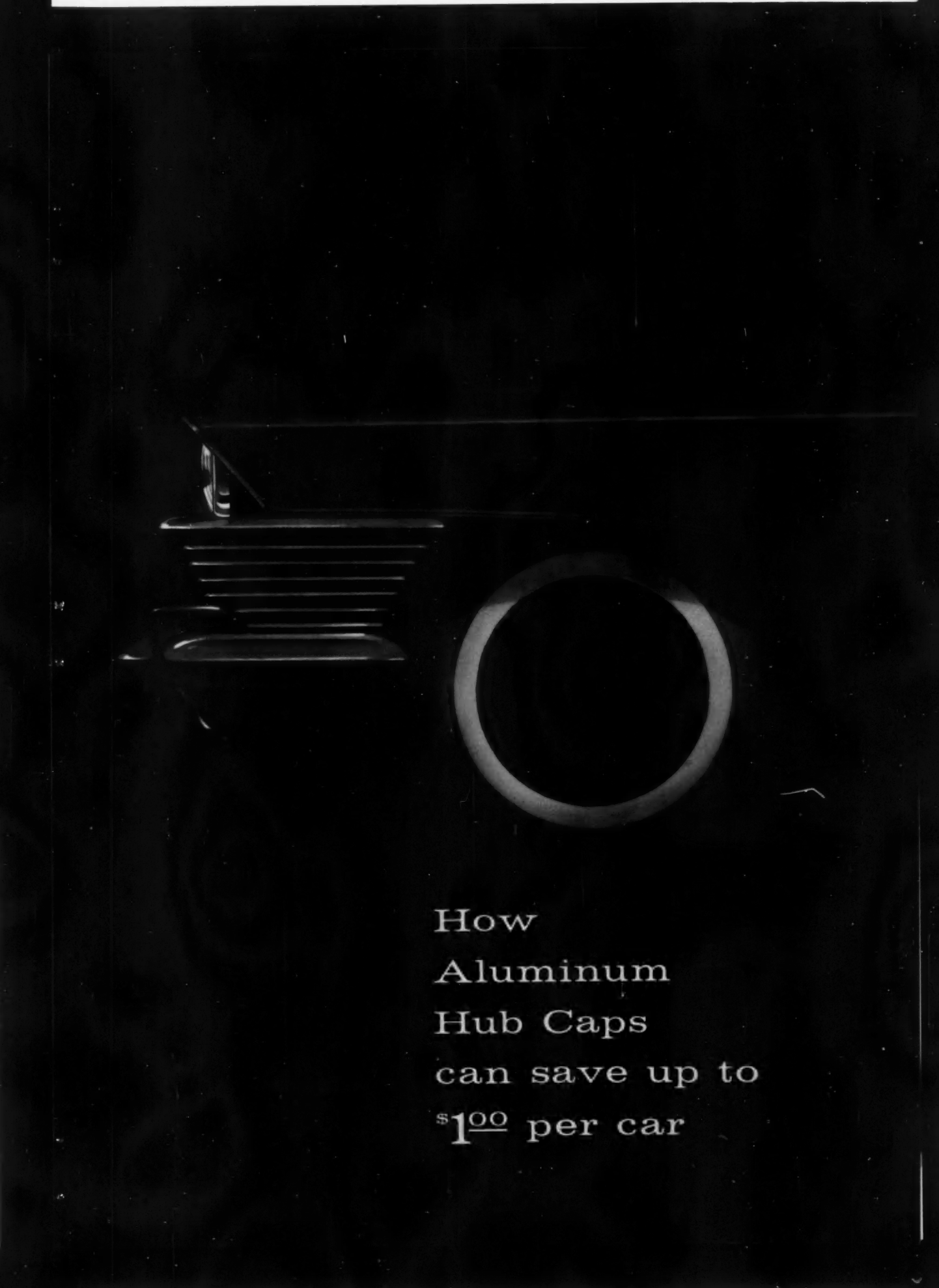
Bendix-Westinghouse

AUTOMOTIVE AIR BRAKE COMPANY

BENDIX-WESTINGHOUSE AIR BRAKES ®

BENDIX-WESTINGHOUSE ★ SINCE 1923 ★ PACEMAKER IN TRANSPORT SAFETY

General offices and factory—Elyria, Ohio. Branches—Berkley, Cal., and Oklahoma City, Okla.


How
Aluminum
Hub Caps
can save up to
$1.00 per car

Aluminum Hub Caps

offer savings in fabricating and finishing, provide greater freedom in design

Recent design and sample fabrication work has pointed out the potential cost savings with aluminum hub caps of from 40¢ up to $1.00 per car (based on four hub caps per car). These savings, like the savings on other automobile parts that are part of the original car cost to the manufacturer, can be substantial per model in a high production year. The total savings, if projected to the automobile industry, would run up to millions of dollars.

These figures of 40¢ to $1.00 are based strictly on fabricating and finishing savings. Savings made possible because of aluminum's ease of fabrication and anodized finishes that are often less costly than finishing processes required with other metals.

From both a cost and design standpoint, hub caps currently being made of various other metals cannot be formed to the degree that aluminum permits, therefore a wider variety of formed details and sharp embossments are possible with aluminum. And even in the case of metals that can be formed to the finer details and deeper cross sections possible with aluminum, there is still a distinct advantage in favor of aluminum. The reason: these other metals require electro-plating or other costly finishing operations. Anodized aluminum finishes are more economical.

Aluminum hub caps offer "bonuses", too. They are strong, lightweight, rustfree. And with their handsome clear or color anodized finishes they can add sales appealing beauty to your fine cars of tomorrow.

Aluminum hub caps (and wheel covers) are one of many automobile applications where strong, lightweight, rustfree aluminum can help you improve parts and reduce costs. For full details, talk to Reynolds Aluminum Specialists. They will help you on individual parts and will also help you plan a cost-cutting aluminum package that includes a variety of parts. And they will bring you details of Reynolds services on aluminum mill products and fabricated aluminum parts. *Contact Reynolds Metals Company sales office at Northland Drive and Northwestern Highway, P.O. Box 5050, Seven Oaks Station, Detroit 35—phone KEnwood 7-5000. Or contact your nearest Reynolds Office or write P.O. Box 2346-MU, Richmond 18, Va.*

NOTE: Before you buy any part—have it designed and priced in aluminum. Basic material costs do not determine part costs. New techniques and processes—applicable only to aluminum—can give you a better product at a lower final cost.

Reynolds Aluminum

the metal for *automation*

TRADE MARK

Watch Reynolds TV show "Harrigan & Son", Fridays; also "All Star Golf", Saturdays—ABC-TV.

ORONITE

presents
the first
ashless
detergent
additive

This new additive offers compounders and oil marketers the opportunity to provide their customers better motor oils. It's being offered alone or in formulations containing zinc dithiophosphate known as Oronite 1200 Series lubricating oil additives.

Developed specifically for low temperature (stop-and-go) gasoline engine service conditions, these new additives also provide good high temperature gasoline and diesel performance. The low ash content offers better control of engine combustion phenomena with resultant lowering of octane requirement increase and reduced surface ignition tendencies.

Both lab and field tests have demonstrated significent advantages from oils compounded with Oronite 1200 Series additives. Why not get the complete story? See how the oil products you produce or market can be made more saleable.

Contact the Oronite office nearest you.

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6962

the new **MICRO-MASTER®** 35mm Camera-Projector by K&E

FIRST with fluorescent lighting. Eliminates hot, troublesome reflector floods, gives better light.

FIRST with curved-field lens. Assures last bit of resolution out of image for highest quality blowbacks.

FIRST with vacuum subject-holder. Holds copy perfectly flat from edge to edge, assures sharper negatives every time.

FIRST with motor-driven projector. Film moves backward or forward for projection at the touch of a button.

FIRST with backlighting. Increases contrast, simplifies reproduction of soiled or two-sided originals.

FIRST with 5-second conversion. From camera to projector in 5 seconds—simple operation assures maximum versatility and output.

A host of technical firsts and *finests* make this the most efficient 35mm unit yet perfected. Specifically tailored for *engineering* miniaturization and reproduction, the new MICRO-MASTER 35mm Camera-Projector enables greater accuracy than any other 35mm unit. The more you learn about this new unit, the more you'll want it. To get the full story, see your local K&E dealer, or fill out and mail the coupon below:

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Gentlemen:

Please send me complete descriptive literature on the new MICRO-MASTER® 35mm Camera-Projector by K&E.

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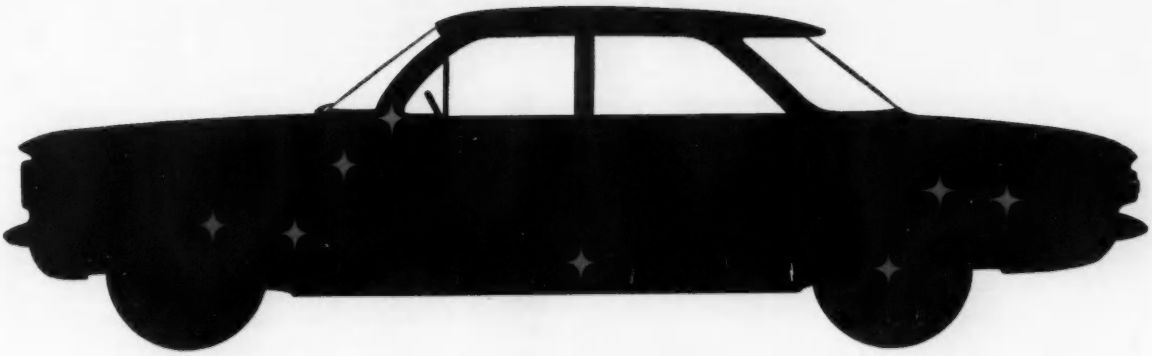
TUBING TAKES NEW TURNS...



...WITH IMAGINATION!

Imagination—the key ingredient in automotive engineering—is taking new turns with tubing at Rochester.

Consider the 1961 Corvair as an example of what imagination is doing with tubing: You'll find Rochester Steel Tubing used as main fuel lines, mast jackets, brake lines, crankcase ventilator tubes, transmission control rods, accelerator rods, and manifold heater intake pipes—among other things.

WHY?

Because Rochester Steel Tubing saves the automotive engineer critical weight and meets his reliability standards. This is a decisive fact proven, again and again, by tests that go beyond specifications.

When you need imagination applied to your engineering problem, contact a Rochester Steel Tubing Sales Engineer. Chances are he can show you how to take a new turn with tubing.

GM

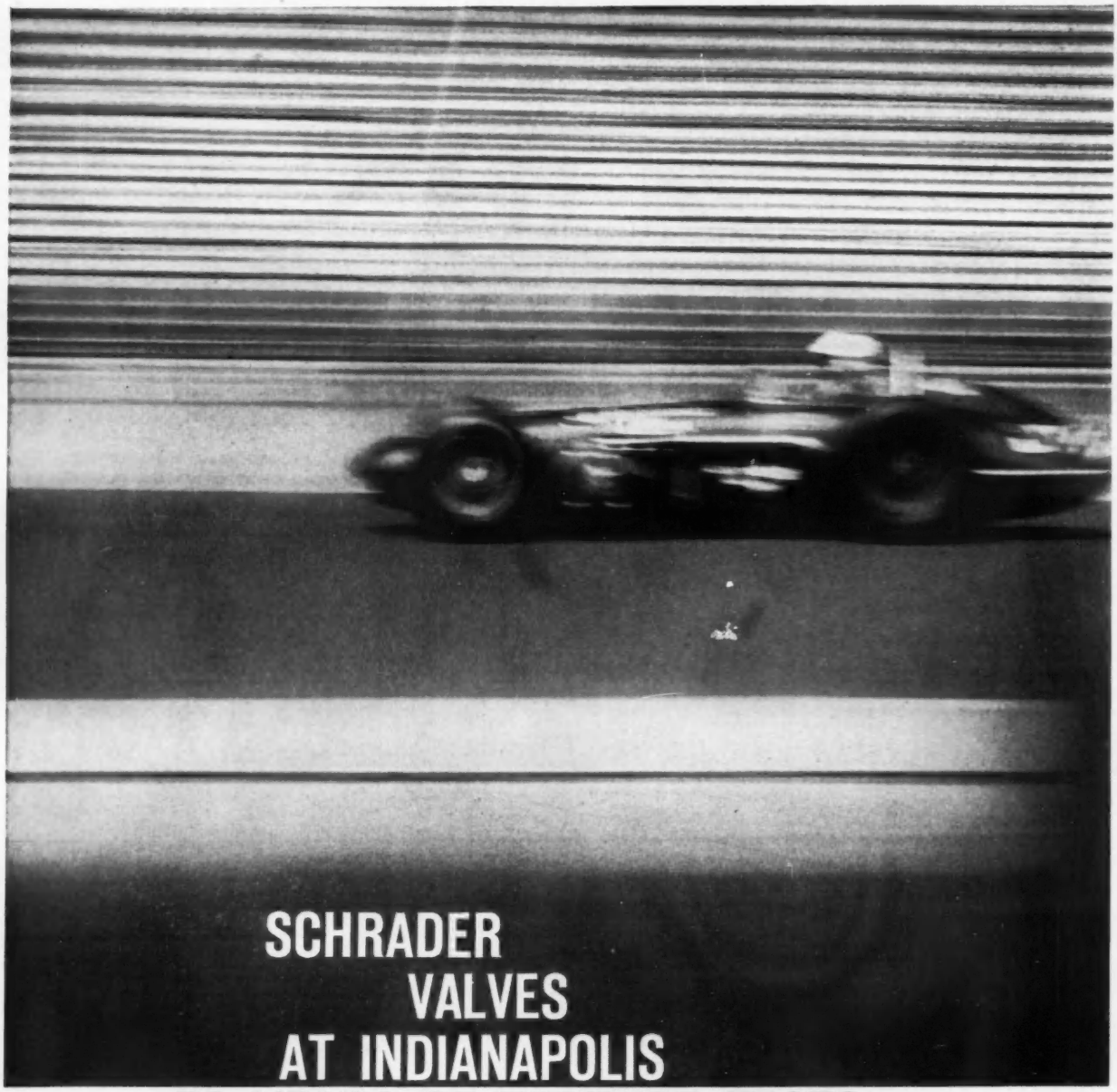
Rochester Reflects Reliability

GENERAL MOTORS

RP

STEEL TUBING BY ROCHESTER PRODUCTS

ROCHESTER PRODUCTS DIVISION OF GENERAL MOTORS, ROCHESTER, NEW YORK

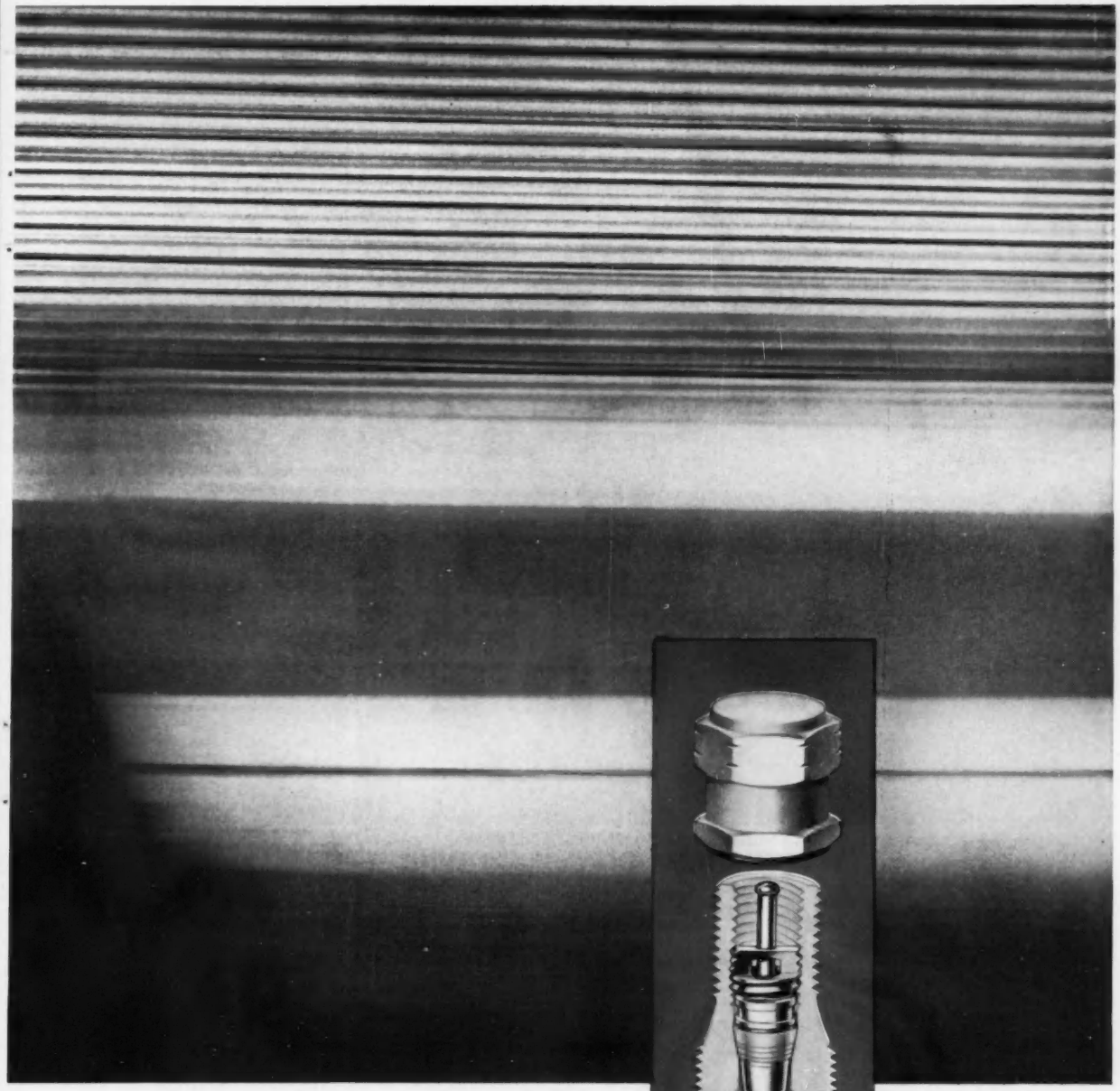


SCHRADER VALVES AT INDIANAPOLIS
50 YEARS OF TORTURE TESTS

For half a century, the Indianapolis Speedway has been the world's most realistic laboratory for testing automotive performance. Most of today's automotive components had to fight their way to become standard equipment by withstanding the pounding punishment of the annual 500-mile race. A cooperative effort of the automotive industries, this Memorial Day event sets a pace equal to thousands of ordinary road tests.

Carrying the whole vehicle while under test themselves, are the tires and the valves. Since the Indianapolis 500-mile race began in 1911, Schrader Tire Valves have been entrusted with the vital job of maintaining the air pressure in the racing car tires. Yet no Schrader valve ever failed.

In spite of the endurance required at burning Indianapolis speeds, the famed Schrader "Ace of Standardization" design supplied for original



Standard Schrader Swivel-T Cores with Teflon plug washers withstand temperatures from −100 to 500°F., have high oil and chemical resistance, make a positive, air-tight seal.

equipment and replacement in the consumer market has always met this classic test. It makes sense to use Schrader valves for any vehicle. There's no comparison in quality anywhere in the world.

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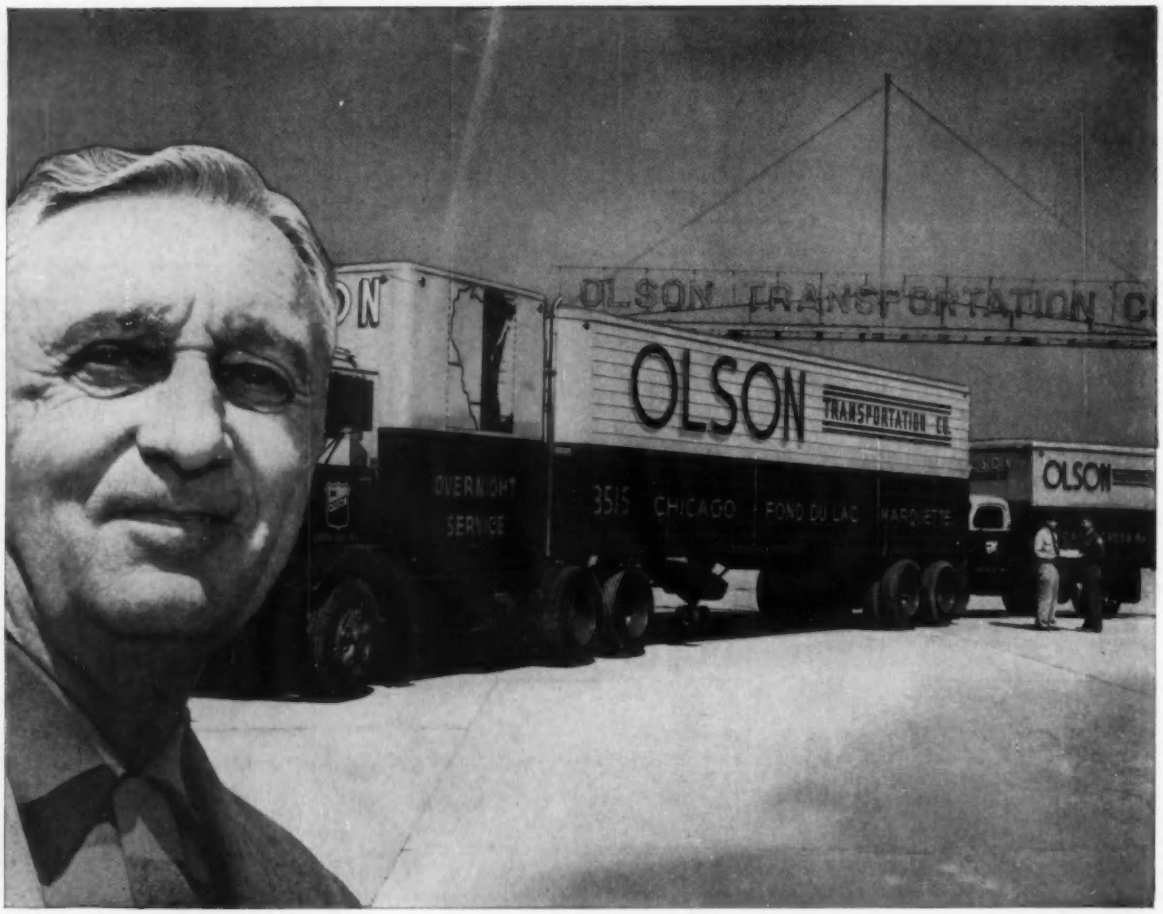
FIRST NAME IN TIRE VALVES
FOR ORIGINAL EQUIPMENT AND REPLACEMENT



"We average more miles with LIPE CLUTCHES"

says Olson Transportation Co., Green Bay, Wisconsin

M. J. Madigan, Olson Maintenance Superintendent, remarks: "Some time back, we decided to give Lipe Clutches a thorough tryout as interchanges for original equipment. Our records show that they have produced more miles before overhaul than the clutches supplied with our units when new. Needless to say, we are very satisfied with these results."

Measure Lipe Clutch value by any standard you like . . . by ton-miles per year, by number of engagements or miles between teardowns, by vehicle use per repair dollar . . . and you'll agree with reports from all over the country that Lipe delivers more profit-building performance per dollar of cost. That's why . . .

***the trend is to* LIPE!**

There is a Lipe Clutch to meet requirements of vehicles 18,000 lbs. G.V.W. and up; for torque capacities from 200 to 3000 ft. lbs. For application assistance and specific data, contact the Company direct.

LIPE ROLLWAY CORPORATION SYRACUSE 1, N. Y.

SAE JOURNAL

For Sake of Argument

Authority . . . or Responsibility?

THE BOSS who doesn't substitute the word "responsibility" for "authority" on his organization chart is in for a rude awakening. Trouble may not knock at his door next week, but it will get around sooner or later.

Some experienced executives check up periodically on their own use of authority as a guide to how well they are administering. "The more I have to give orders, the less leadership I'm exercising," one top executive opined the other day. Then added: "And everybody knows a group that is led will always go further and faster than one that is driven."

What he's saying is that any supervisor's progress is inversely proportional to the number of times he relies on authority *per se* to get results. Maybe, on the other side, he could give himself a silver star when a subordinate picks up one of his ideas and does something with it before an order becomes necessary.

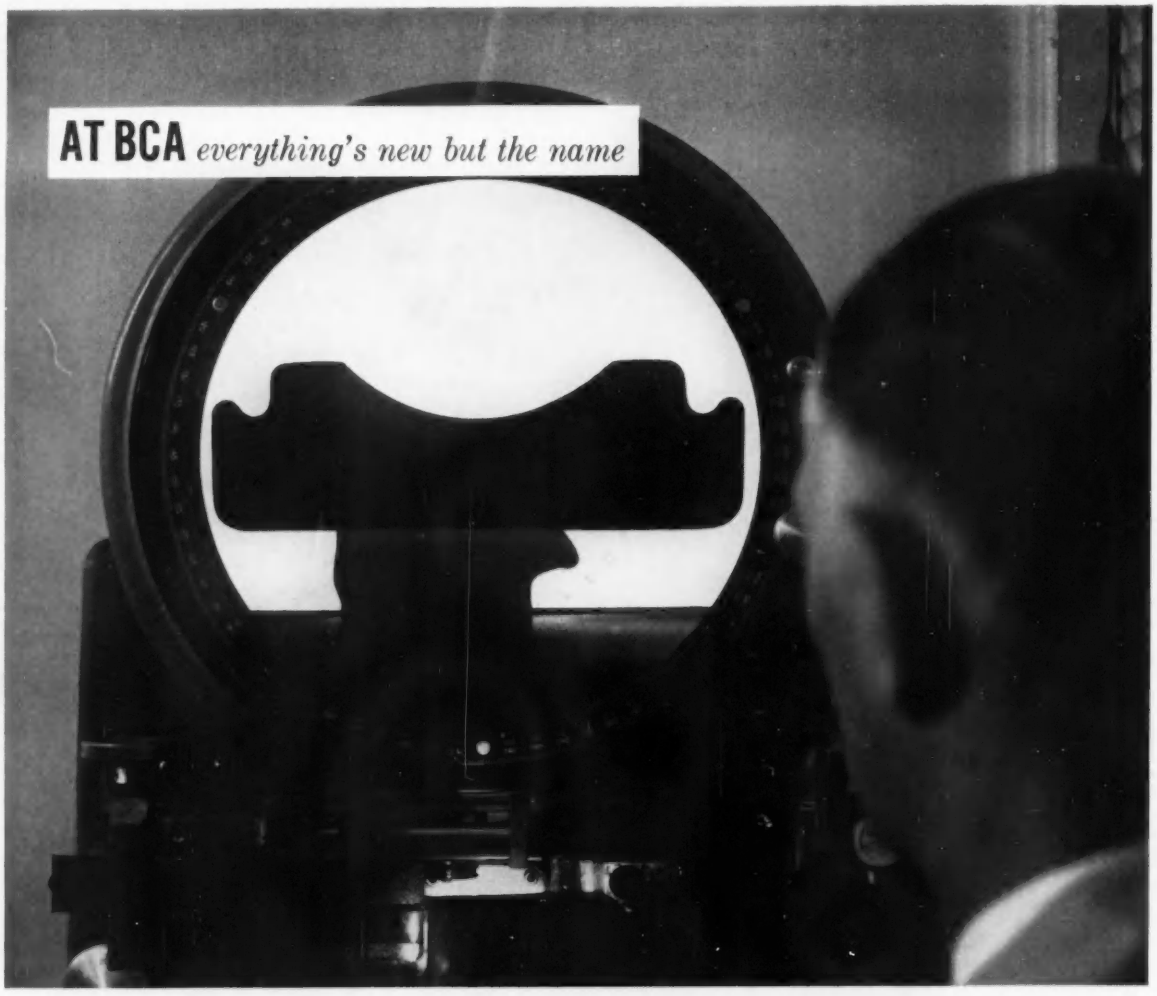
Some supervisors give orders instead of selling ideas because it's easier — at the moment anyhow. A fair amount of order-giving is due as much to the supervisor's being busy as to his being autocratic. But that doesn't improve the results which accrue.

Some of the bad results of order-giving bounce back to the boss himself. Habitual use of the big stick, for example, can dull sensitivity and ability to use other more delicate tools of administration. And these more delicate tools become increasingly necessary as an upward climb goes on.

The man with high capacities for supervision will rarely use the powers given him; yet he *must have* the authority or he's licked before he starts.

Both management and employees usually rejoice in the executive versatile enough to get results by muting, rather than accentuating, the authority string.

Norman G. Shidle



BIG PICTURE—100 TIMES ACTUAL SIZE—

checks ball bearing geometry

BCA engineers take a close, "big" look at the configuration of inner and outer rings of ball bearings with this contour projector. It magnifies profiles up to 100 times actual size—makes possible extremely accurate measurements and control of all geometric characteristics of raceway rings.

This contour projector provides essential information for BCA research in developing new and modified bearing designs. It also evaluates the production performance of precision tools and machine set-ups by checking the profiles of production raceway rings against precise design specifications. This device is only one of many BCA quality control measures that help assure uniformly high ball bearing quality.

New BCA laboratory facilities also include a variety of specially designed testing machines that simulate actual or exaggerated operating conditions. On this equipment, bearings are studied under exact operating conditions of the customer's application . . . and tested to *exceed* his specifications.

BCA ball bearings for original equipment as well as replacement use are made in a complete range of types and sizes. They serve practically every kind of industry . . . automotive, machine tool, construction and agricultural equipment, to name a few. For complete information, for experienced engineering counsel on bearing applications, contact: Bearings Company of America, Division of Federal-Mogul-Bower Bearings, Inc., Lancaster, Pa.

BCA

BEARINGS COMPANY OF AMERICA

ball bearings

DIVISION OF
FEDERAL-MOGUL-BOWER
BEARINGS, INC.

chips

from SAE meetings, members, and committees

BUSINESS AIRCRAFT FLEET will account for 40% of all U. S. civil aircraft by 1975 — as against its present 33% — predicts Ford's A. R. Bergeson. The 1975 fleet of 46,000 business-use aircraft is expected to fly about 16,575,000 hr . . . or 65% of the total 25,500,000 hr forecast to be flown by general aviation. . . . Some 20,500 of the 46,000, it is expected, will be single-engined, 3-or-more place planes . . . 500, heavy multijet types.

A PRIZE OF £5000 has been offered for the first British man-powered aircraft flying a figure-eight mile around pylons. Also £1000 has been made available to aid builders of "flying bicycles." There is interest in the project in some of the British universities.

CORROSION PREVENTION continues to get special attention from designers working on aluminum engine structures.

Among the steps taken by Chrysler engineers on their new slant-six engines, for example, are these: (1) Surfaces of the water-pump-inlet and cylinder-head-outlet castings in contact with radiator or heater hoses are coated with special corrosion-resistant paint; (2) synthetic rubber-coated gaskets prevent corrosion resulting from seepage at gasket surfaces of the water-pump and cylinder-head-outlet castings; and (3) use of copper in the cylinder head gasket and brass for thermostat parts was ok'd when tests proved they did not result in measurable galvanic corrosion of aluminum cylinder blocks or outlet castings. (The ratio of the area of copper and brass to the area of aluminum is very low, and the small amount of galvanic corrosion occurring with aluminum is spread over a very large area.)

Other Chrysler tests, incidentally, indicate that general corrosion of the engine's aluminum components won't be any more severe than with cast iron and steel components.

RUSSIAN AND FRENCH STARLINGS are apparently unaffected by distress-calls from birds of different origin. Broadcasting recordings of such calls over the loudspeaker at an airport near Copenhagen has proved effective, but not against starlings migrating from these countries.

A Dutch engineer produced the recordings by putting starlings into a net and shaking them up.

TEMPERATURE GOALS for space vehicle lubricants are, reported to be:

Hydraulic fluids: 800 F
Greases: 800 F
Dry film lubricants: 1700 F
Organic fluids: 850 F
Gases and vapors: 1600 F
Liquid metals: 1400 F

AT 40 MPH, any one part of the average tire is in contact with the road for about 1/100 sec.

FREEZING ANTIKNOCK REQUIREMENTS of new cars at present levels for the next five years would still necessitate a substantial boost in gasoline antiknock quality. Specifically, it is estimated that the average octane number of regular gasoline would have to increase by 2.6 units (or the percentage of premium gasoline sold would have to increase by 35%). Reason: there would still be the normal replacement of old, low-compression vehicles with the newer ones of higher octane requirements. Thus, a higher-octane gasoline would be needed if regular gasoline is to satisfy the octane requirements of the same percentage of cars as does present-day regular gasoline.

MOON DUST which has accumulated over many aeons, can prove immeasurably important to the biological sciences, if organic molecules are turned up. These precursors of living organisms may give us a clue to the development of physical life on earth. Organic molecules have already been detected in the interior of meteorites.

AT FORD ALONE, today's consumption of gaseous-shielded, automatic arc welding electrodes amounts to about 1,000,000 lb per year . . . and Ford consumes somewhere in the neighborhood of 10,000,000 cu ft of carbon dioxide shielding gas. Products welded by this process include starter and generator frames, rear axle housings, frames, automatic transmission components, and bodies.

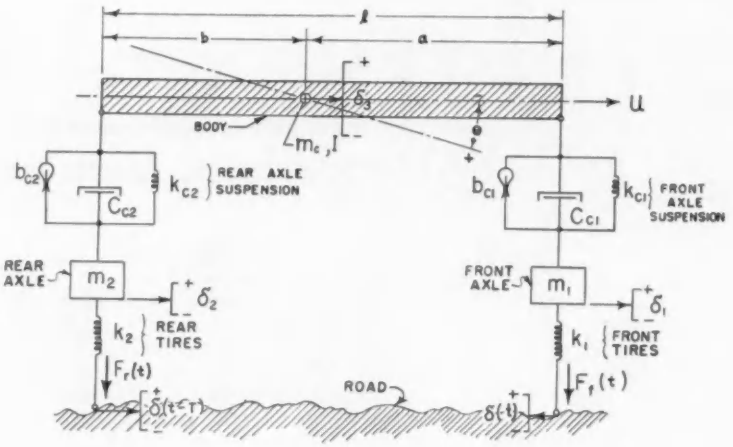


Fig. 1 — Mechanical analog of a truck, from which the electronic analog is fashioned. The symbols are defined as follows:
k_1 and k_2 = front and rear tire spring rates, respectively
k_{c1} and k_{c2} = front and rear axle suspension spring rates, respectively
C_{c1} and C_{c2} = front and rear axle viscous damping constant, respectively
b_{c1} and b_{c2} = front and rear axle Coulomb friction force, respectively
m_1, m_2, and m_c = front and rear axle, and sprung mass, respectively
δ_1, δ_2, and δ_3 = absolute front axle, rear axle, and body position, respectively
$F_f(t)$ and $F_r(t)$ = front and rear tire dynamic road loading force, respectively
I = body pitch inertia about the center of gravity
Other symbols are defined in the article.

How an analog computer can help to . . .

design suspension systems

It provides a valuable analysis, when backed up by road tests. The effects of changing suspension parameters are predicted.

Based on paper by

D. C. Clark

Cornell Aeronautical Laboratory, Inc.

THE forces acting on a road due to the action of the vehicles traversing it may be predicted with the aid of a mathematical model of the vehicle. These forces are the result of the reaction of the vehicle suspension to the variations in the road profile. Since the road and the vehicle are so closely allied in their reactions and interactions, they can each be considered as components of an integrated highway-vehicle system. But, preliminary analysis of the system can be performed by studying each component seperately. This is the purpose of developing a vehicle model.

The two parts of the highway-vehicle system may be separated at their point of contact, the tire print. The road exists on one side of the print and the vehicle on the other. The road profile that is presented to the vehicle is a function of the road as constructed and its subsequent modifications by wear, weather, age, traffic history, maintenance, and the dynamics of the road as an elastically supported body.

The vehicle applies loads to the road through the tire contact print. This load varies as the vehicle moves along the road. The tires are loaded by the unsprung masses, or axles, which in turn are loaded by the suspension springs. The springs receive their load from the sprung mass of the vehicle. Any change in the deflection of the elastic members causes variation in the load applied to the road. Since both the road and the vehicle are elastically supported, the output forces applied by the vehicle to the road are frequency dependent. Like many dynamic systems, mechanical resonance occurs at certain frequencies and magnifies the transmitted loads. This is important since the fatigue life of a material decreases at a greater rate than an increase in the load. Thus, if resonances cause the dynamic load to be doubled, the life of the pavement at the higher stress level would be less than 50% of the expected life at the lower stress level. The same effect applies to the vehicle.

Besides these vertical loads, excited by the road profile undulations, horizontal forces also exist. These are due to transient accelerations, braking, steering action, wind loads, road camber, and superelevation of the road. However, the majority of highway travel occurs over straight, relatively flat roads, at constant speed. Under these conditions the major forces are vertical. Since the horizontal

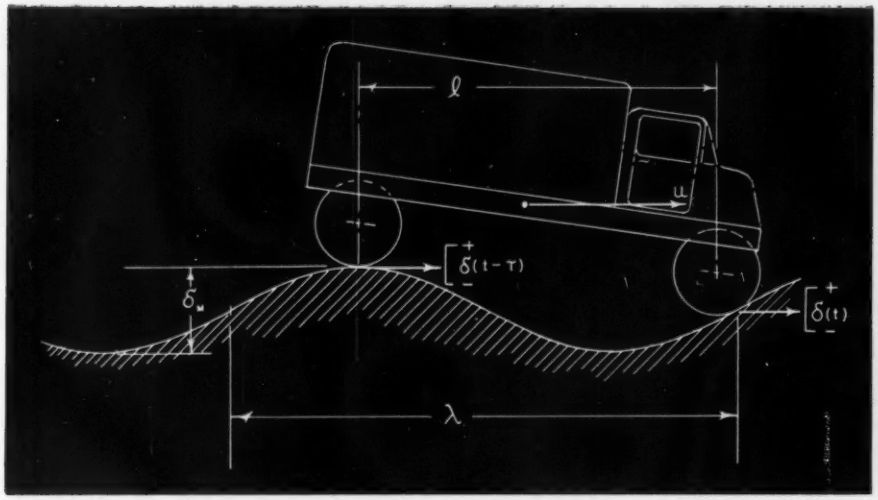


Fig. 2 — Sinusoidal road input. This represents a worst case, since the vehicle is subjected to concentrated frequency vibration conditions. The symbols are defined in the article.

loads are relatively transient, a preliminary analysis need not deal with them.

Synthesizing a vehicle

A mathematical model of the vehicle helps to determine the road load forces resulting from given input road profile variations. It allows rapid and accurate evaluation of the effect of parameter changes upon load force intensity. Ride qualities, such as jerk, can be computed simultaneously with road load forces to achieve compromise, where necessary, in suspension design. With this model the smoothing effect of shock absorber action is clearly indicated.

The mathematical model of the vehicle can be based on the mechanical analog of a pneumatic tired vehicle with lumped parameters, shown in Fig. 1. For reasons of simplicity only four degrees-of-freedom are considered; sprung mass pitch and heave, and the two unsprung mass (front and rear axle) degrees of freedom. Turning, rolling and lateral translation are omitted since they are a relatively infrequent part of highway travel.

Also to be accounted for are nonlinearities of the suspension system. The components of the vehicle's suspension system are all nonlinear to some degree. Tires, suspension springs, and shock absorbers generally have nonlinear deflections. There is also an appreciable amount of Coulomb friction in the typical suspension system. Coulomb friction opposes relative motion of the friction elements and is independent of deflection amplitude. Another source of nonlinearity is the possible loss of contact between the tires and pavement. When this occurs, the tire spring force is removed from the axle, since it cannot become negative. Only the two most critical of these nonlinearities are included in the model. These are Coulomb friction and a nonlinear axle force-displacement due to tires leaving the road.

The parameters selected for the study are representative of a two-axle truck carrying a load of twelve tons, placed such that the center of gravity of the sprung mass is eight feet aft of the front axle for a twelve-foot wheelbase. Since the model is half-width all mass and inertia terms are halved. The parameters are given in Table 1 and defined in Fig. 1.

Inputs to the model

The inputs to the model are the perturbations of the road surface. No clear cut definition exists of what constitutes a representative road profile. However, it has been observed that sections of road profiles can be very closely approximated, for limited distances, by simple wave functions of a sinusoidal, triangular, or square nature. As a worst case, a single frequency sinusoidal road profile can be used as the input. This subjects the vehicle to concentrated frequency vibration conditions.

Obviously, the inputs to the two tires have a difinite phase relationship. The same profile that deflects the front tires, $\delta\ (t)$, is assumed to occur at the rear tires τ seconds later to become $\delta\ (t-\tau)$. The

Table 1 — Assumed Model Truck Parameters

Parameter	Truck Loaded	Truck Unloaded	Units
m_c	31.1	7.0	lb-sec²/in.
m_1	1.30	1.30	lb-sec²/in.
m_2	2.59	2.59	lb-sec²/in.
k_{c_1}	900	900	lb/in.
k_{c_2}	2000	2000	lb/in.
k_1	4500	4500	lb/in.
k_2	9000	9000	lb/in.
c_{c_1}	100	100	lb-sec/in.
c_{c_2}	0,200[a]	0	lb-sec/in.
b_{c_1}	300	300	lb
b_{c_2}	400	400	lb
I	87,000	28,700	in.-lb-sec²
a	96.0	53.3	in.
b	48	90.7	in.

[a] Without and with rear shock absorbers, respectively.

time delay at a constant forward velocity is equal to the ratio of wheelbase length to the forward velocity. Fig. 2 demonstrates the relationships between the various parameters for a sinusoidal input.

The frequency of the input depends not only upon the road profile wavelength, λ, but also upon forward speed, u. This frequency is equal to u/λ. The space phase angle between the forward and rear inputs is given by $\phi = 2\pi l/\lambda$, for a fixed wheelbase, l.

Response to inputs

The vehicle model response to sinusoidal road profile inputs is typified by the curves of Fig. 3. These results were obtained from an electronic analog computer set up to simulate the lumped parameter mechanical analog. The outputs shown represent the vertical road load forces as a function of time, after the decay of all suspension transients. Although the curves of Fig. 3 represent just one input displacement at one input frequency several conclusions may be drawn from it. The effect of shock absorbers in decreasing the peak dynamic road load is unmistakable. With shock absorbers on all axles, the peak dynamic road load force under the rear tires is only 50% larger than the 9000-lb static lead. Without shock absorbers on the rear axle, (all other things being equal), a 300% increase occurs. It may be noted that without shock absorbers, the rear tires leave the road every time the axle bounces (as evidenced by the load dropping to zero). This condition is especially pronounced for the case where the truck is unloaded. Under this condition the peak to static road load force is about 7.5/1, at wheel hop resonance.

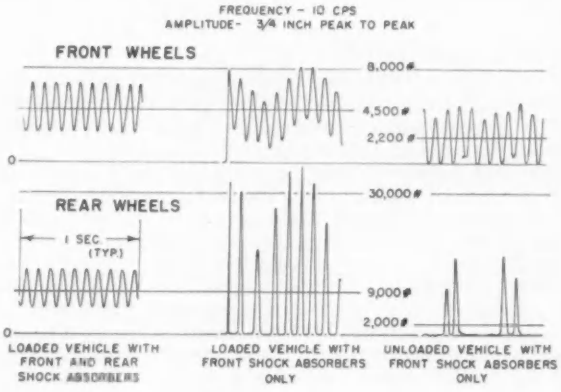


Fig. 3 — Response to sinusoidal road input. Road load forces are plotted against time. The smoothing effect of shock absorbers is evident. The rear tires are seen to leave the road every time the axle bounces.

Analog computer records, taken at various space phase angles between front and rear axles, at a fixed wheelbase, showed road load to be unaffected at any frequency. This effect is attributed to the low frequency vehicle pitching response, essentially isolating front and rear wheel hop effects. This insensitivity to phase angle allows the information from only one frequency response plot to be extended to all combinations of speed and wavelength. This is evident from the fact that a different wavelength will produce the same input frequency at a new speed. For example, a shorter wavelength results in a given excitation frequency to the vehicle at a lower forward speed.

Another useful plot is that of the steady state dynamic road load to the static load, as a function of frequency (u/λ). Fig. 4 is such a plot for the case of the unloaded vehicle without rear shock absorbers. Input amplitudes, δ_m, of ¼, ½, and ¾ in. were used. Each of the points on the curves can be applied to a multitude of speed and wavelength combinations. Although the wheelbase to wavelength ratio of this plot is fixed, the character of the loaded vehicle curves is not altered greatly by changes in this ratio.

These curves demonstrate that at least twice the static lead can readily be obtained over a fairly broad frequency range, with moderate amplitude inputs. Most road profiles will excite the wheel hop mode to some degree at almost any speed.

To Order Paper No. 310B . . .
from which material for this article was drawn, see p. 6.

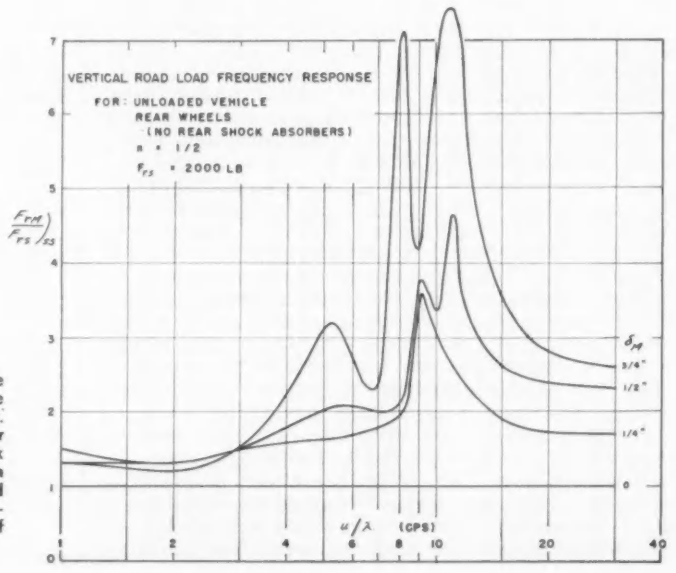


Fig. 4 — The ratio of steady state maximum to static road load force is plotted against input frequency. Evident here also, is the high rear axle forces in the absence of shock absorbers. Each of the points can be applied to a multitude of speed and wavelength combinations, making this a very useful means of presentation.

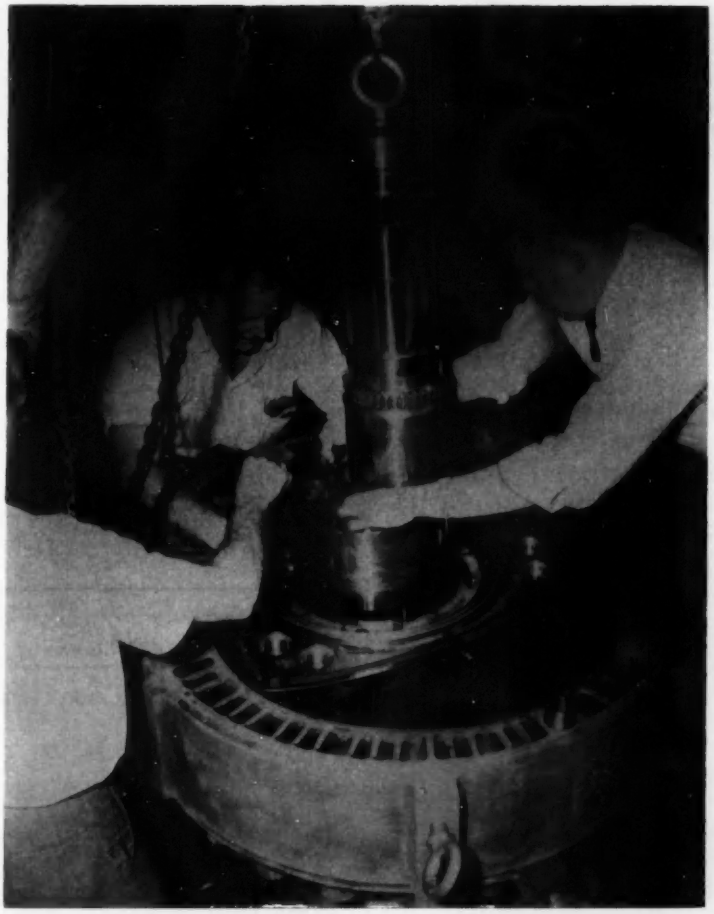


Fig. 1 — Size of RC19 engine can be visualized from this view showing assembly of power section.

New Rotating Combustion Engines by Curtiss-Wright

• 780-hp single-rotor engine. • 4-rotor engine.

Based on paper by

M. Bentele

Curtiss-Wright Corp.

TWO rotating combustion engine configurations being studied at Curtiss-Wright are:

- 780-hp single-rotor engine.
- 4-rotor engine.

Large engine

To investigate the size effect on various engine phenomena, the linear dimensions of the first CW experimental engine, known as the RC6 (60 cu in. displacement), were blown up about three times, to a displacement some 30 times greater, namely, 1920 cu in. (See Fig. 1.)

Only dimensions and features that affected stresses, heat transfer, and thermal gradients were adjusted in this engine, known as the RC19. Otherwise, the configuration of the RC6 was retained. The RC19 has dual side ports, each connected to a carburetor with manual control.

The operation of this engine has been normal, with breathing capacity proving ample, even at high apex velocities.

Although preliminary tests demonstrated the power potential of this engine size, it did exhibit

PRESENTED herewith is the third of a series of articles that are bringing to SAE Journal readers up-to-date information on new developments in the rotating combustion engine field, both here and abroad.

The previous articles were:

- **"CW Rotating Combustion Engine," R. T. Hurley. SAE Journal, June 1960, pp. 80–85.**
- **"NSU's Progress Report on Rotating Combustion Engines," W. G. Froede, SAE Journal, April 1961. pp. 50–56.**

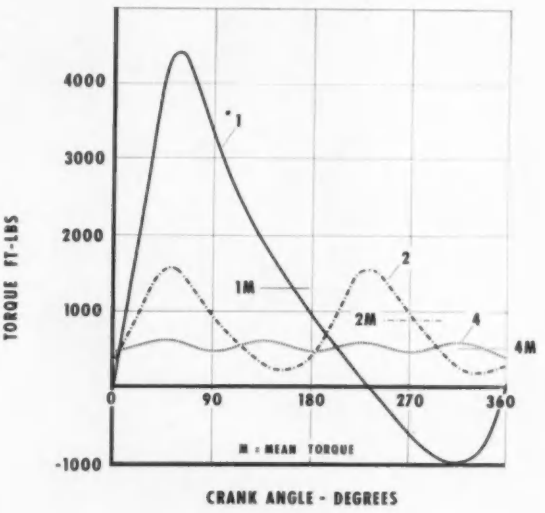


Fig. 2 — Instantaneous rotor torque of single-, twin-, and 4-rotor engines (450 hp), all with geometrically similar power sections and equal apex velocity. Note that the twin eliminates the negative torque of the single, and its torque peak is considerably lower than that of the single. The 4-rotor engine gives a very small torque variation. The mean torque decreases for the twin and four because of their smaller trochoid sizes and correspondingly higher rated speeds.

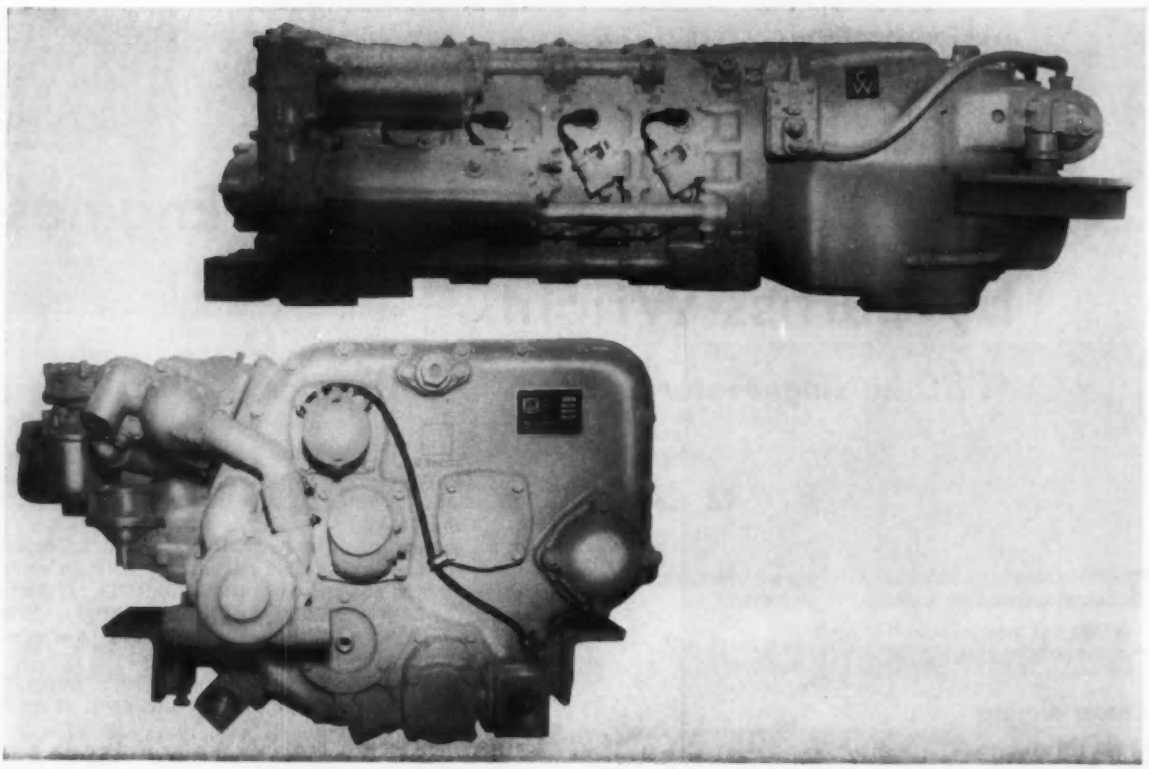


Fig. 3 — Four-rotor engine 4RC6 viewed from rear and from spark-plug side.

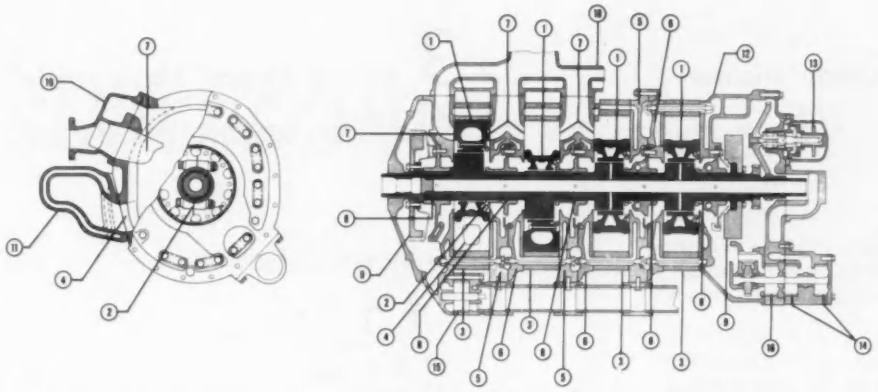


Fig. 4 — Cross-sectional and longitudinal views of 4RC6 engine. The integral crankchaft has been accommodated within the intermediate side housings by splitting these in a plane perpendicular to the engine axis and by splitting the bearings and stationary gears in a plane including the axis, as shown.

1. Rotor
2. Split stationary gear with main bearing
3. Rotor housing
4. Exhaust port
5. Side housing — drive side
6. Side housing — anti-drive side
7. Intake port (dual intake)
8. Main bearing
9. Flywheel cum balance weight
10. Intake manifold
11. Exhaust manifold
12. Accessory gear box housing
13. Ignition contact makers
14. Oil pressure pumps
15. Oil scavenge pump — front
16. Oil scavenge pump — rear

New rotating combustion engines by Curtiss-Wright

. . . continued

detonation. This phenomenon had not occurred on the engines of smaller size. It took place when standard fuel-air mixtures and full-throttle opening were approached. For this reason, attractive power and fuel consumption figures could not be realized in the first series of tests. Further investigation of this deficiency is required. It is too early to say that the size of the combustion chamber is the main cause of the detonation. On the other hand, the engine helped to clarify other phenomena that were exaggerated by the size, and so could be more readily investigated than on the smaller engine.

Table 1 gives the initial performance of the RC19.

4-rotor engine

A 4-rotor engine has a much smoother instantaneous rotor torque curve than does a single-rotor engine, or even than a twin-rotor unit, as shown in Fig. 2. The 4-rotor engine data in this graph were obtained from tests of the engine shown in Figs. 3–5.

The following configuration was selected, based on components of the RC6 engine: inline arrangement of the major trochoid axes, which means inline intake and exhaust ports and spark plugs, an integral one-piece crankshaft, uninterrupted sealing faces for the side housings, and parallel flow of the coolant and lubricant through the four power sections. The parallel flows had, apart from their design advantages, the additional factor that all analytical and test results from the single unit could readily be applied to the four-rotor engine.

The crank arrangement provides for power strokes at 90-deg intervals, with a 1–4–2–3 firing order. It does leave, however, a small couple, which has to be

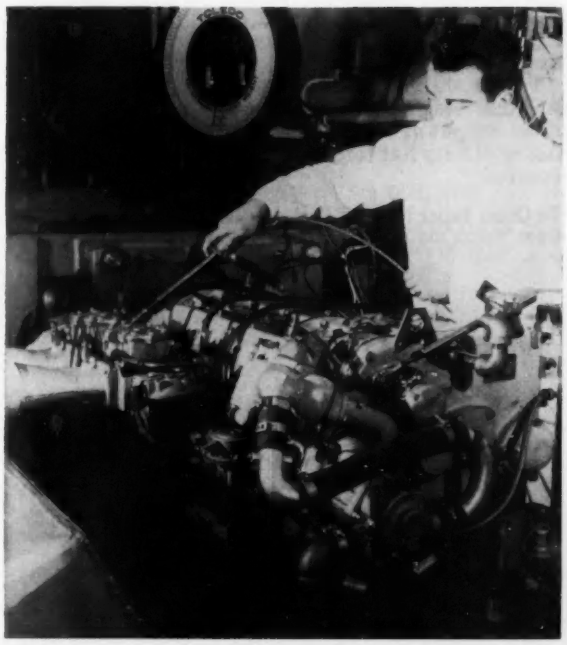


Fig. 5 — Three-quarter view, from carburetor side, of 4RC6 engine on test stand, with engine accessories and conventional instrumentation.

Table 1 — Initial Performance Data for RC19

Power at 1525 Rpm, bhp	782
Bmep, psi	106
Volumetric Efficiency, %	83
Brake Specific Air Consumption, lb/hr/bhp	7.9

New rotating combustion engines by Curtiss-Wright

. . . continued

compensated for by a balance weight at either end of the shaft. This penalty is not serious, since an additional torsional mass is probably desirable, in any case.

The crankshaft serves as oil supply to the power sections. The return oil is delivered to the oil cooler and oil tank by two scavenge pumps located at the lower front and rear ends of the engine.

The coolant is distributed by a tube along the housings, from which it flows to the intake manifold, thus heating it for better fuel distribution at low temperatures.

Two carburetors and dual side ports are used to give good air and fuel distribution. As Fig. 3 shows, this engine was designed for low height and short length.

Fig. 6 shows full-throttle performance of the first test engine, culminating in a maximum output of 425 hp at 6500 rpm, and showing relatively flat torque and fuel consumption curves.

To Order Paper No. 288C . . .
from which material for this article was drawn, see p. 6.

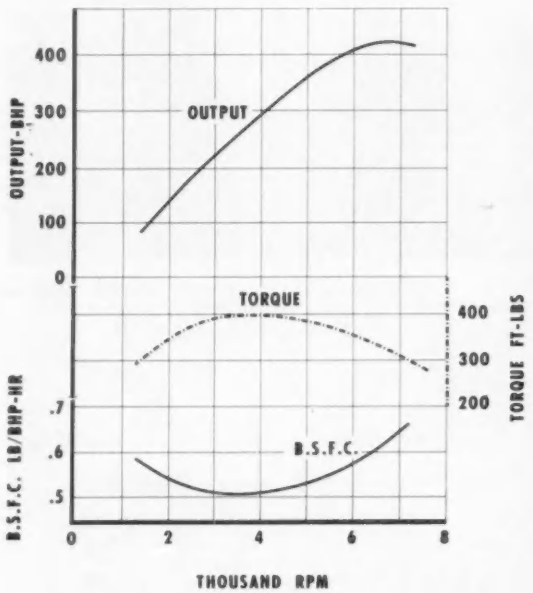


Fig. 6 — Performance data for 4RC6 engine. Note relatively flat torque and fuel consumption curves.

3 pilots speak their minds on design requirements for Airplane

Excerpts from paper by

W. W. Moss,
captain, Pan American World Airways

J. R. Gannett,
chief engineering pilot, Boeing Airplane Co., and

P. H. Patten,
engineering test pilot, Douglas Aircraft Co.

WE think that humanly guided automatic control may be desirable, but fully automatic control for the whole flight is years away and we believe that it really isn't necessary anyway.

Because of noise restrictions, subsonic operation will probably be used to about 35,000 ft on climb and below about 50,000 ft on descent. So we will probably have essentially the same type of terminal area operation as we have today. Therefore, human control should be perfectly feasible because the problem, except in the fuel consumption sense, is roughly of the same magnitude as at present.

However, some people say subsonic control and stability may be largely dictated by supersonic performance considerations. We prefer to put it a different way. The handling characteristics *throughout the flight regime* must be the *bench mark* and supersonic performance problems must be solved as far as humanly possible without prejudice to the handling qualities.

In general, present stability and control criteria appear to be valid as far as they go. But problems have arisen in regard to lateral-directional characteristics, rudder requirements, longitudinal control requirements, and approach configuration speed stability.

Lateral-directional characteristics

More emphasis should be placed in the area of the aircraft's dynamic response characteristics in order to improve the overall handling qualities of the high performance air transport.

If the aircraft configuration is established largely from performance considerations, highly reliable artificial or auxiliary means may be used to make these improvements. Many researchers have done

SUPERSONIC transport

• handling characteristics and • landing performance

Handling Characteristics

an excellent job of defining in parameter form the desirable handling characteristics as determined by pilot evaluations. The discussions on the Dutch roll mode damping ratios, the studies on the roll mode time constant, and the ratio of roll to sideslip motion as well as the comments from the pilots who took part in these tests all correlate nicely with our experience in flying the high performance airplanes. The situation can be summed up by saying:

The optimum handling characteristics are quite easily defined and can be stated quantitatively fairly accurately as a result of these studies. However, further research should be conducted to establish the validity of these criteria as applied to large transport airplanes.

Need for this type of research arises when the design engineers require clear definition of the required airplane handling qualities. It appears to us to be necessary that the supersonic jet transport be designed so that the *optimum* handling characteristics are made a part of the machine in one way or the other. Stability augmentation on all three axes with a number of backup black boxes available might be the only practical way of incorporating the desirable handling characteristics in the high-speed transport without unduly sacrificing the performance capabilities. So, it is felt, a new concept regarding black box reliability must be adopted: **Any electronic or other means of augmenting stability should possess a level of reliability comparable to that of the basic control system.**

Black box reliability is often penalized because of weight and size limitations. This penalty cannot be tolerated in cases where airplane handling characteristics are affected.

The optimum characteristics, we feel, are:

- **Aileron control** displacement and force should command *roll rate* primarily, or possibly displacement.
- **Elevator control** displacement and force should define **pitch rate** or an increment of airplane speed change from the original trim point.
- **Rudder control** displacement should define *yaw rate or sideslip engine.*

Any noticeable amount of lag or overshoot after a control input in either the roll rate, pitch rate, or yaw rate detract from good controllability and are very undesirable.

It is felt that the tailoring of the proper handling characteristics can reduce the required training to some extent and thus lower the total cost of training for the next series of airplanes.

A pilot can sit in a simulator and show his reaction to certain sets of stability derivatives and comment on their desirability. But it is another thing to carefully analyze the instinctive reactions of a pilot who has been flying twenty or twenty-five years in scheduled airline operation when he is making an instrument low approach in rough air and has to successfully and smoothly land on a 150-ft wide, wet, slippery runway. Under these moments of stress, **the pilot reverts to instinctive and conventional control handling and the airplane must respond in an acceptable manner under these conditions.**

The design engineer must realize that the supersonic jet transport must possess *optimum* handling qualities and that he should not settle for the minimum acceptable handling qualities. It goes without saying that the linearity of response is quite important. For instance, the curve of wheel force and

displacement versus aileron effectiveness and roll rate should be essentially a smooth line, with no sudden changes in slope which could lead to sudden under- or over-controlling. This can be done with the control system being essentially a rate or displacement ordering system and not an acceleration ordering system. It is extremely important that the pilot-airplane loop be quite tight. No noticeable amounts of lag or spurious airplane motions should be present after a given control input.

The condition that occurs when a control input introduces other spurious and undesirable motions is as follows:

With present jet transports, the engine locations on the wings and the yaw-roll characteristics introduce a situation which occasionally can be somewhat bothersome, particularly during the instrument aproach. When all four throttles are advanced simultaneously one engine may put out more thrust than another, due to the individual engine response and trim characteristics. Consequently, a yaw motion is introduced, followed by the associated roll motion due to yaw. This is particularly prevalent and especially undesirable during an ILS approach, where the pilot's attention is largely given to his flight instruments and where thrust adjustments are usually made by feel rather than by reference to engine thrust indicators. Result: a pilot, unless he is careful to establish the right symmetric thrust level early in the approach, never really gets settled down directionally. He has to make small bank angle and directional corrections which would not otherwise be necessary.

The need for decoupling roll from yaw is fairly obvious in this particular instance.

Rudder requirements

The pilot's use of the rudder on a modern jet transport is largely confined to three situations:

1. Keeping the aircraft straight on the ground during take-off and landing.
2. Kicking off the drift during the flare for a crosswind landing.
3. Controlling the yaw due to asymmetric thrust (the engine cut case).

To satisfy these three requirements, rapidity of response and sensitivity around the neutral point are extremely important for precise directional control during landings and take-offs. Need for this precise directional control during landing and take-off has become more apparent recently because of the shortcomings of differential braking on wet runways and the poor effectiveness of differential reversing. Aerodynamic controls are as important for jet airplanes during landings and take-offs for control on the ground as they were for piston transports of the past, if not more so.

The design engineer tends to satisfy the static control requirements without providing:

- Enough excess control left to satisfy the dynamic requirements always present in line operation.
- An airplane response rate capable of providing the precise control necessary.

The rudder is a prime example where excess control is required to cope with the dynamic conditions, and where the response rate is of great importance to provide good controllability.

It is one thing for an experimental pilot to take an engine cut six or eight times a day in a test program to demonstrate a given airplane. It is another thing for an airline pilot who may not ever have had an engine failure on take-off except during training (where he is alert to the possibility) to handle the airplane successfully. Consequently, the response rate and the controllability must have a large margin to compensate for the routine and average reaction time, as well as the adverse weather conditions that occasionally exist during normal line flying. The rudders on the current series of jet transports represent satisfactory characteristics in general and are acceptable with respect to desirable levels of rudder effectiveness and response rate. As engine thrust values and airplane performance increase, however, the rudder may be pushed to its limit . . . a tendency which we think should be resisted.

An additional requirement of rudder effectiveness is the 2-engine-out-on-the-same-side situation. While present jet engine reliability rates would seem to make this quite unnecessary, the future trend of such rates is wholly speculative. So, the pilot must still plan for an occasional double-engine-failure landing.

This rarity, of course, poses a special handling problem. It calls upon the pilot to perform a maneuver he does very rarely, and then only in training. So, the aircraft handling should not be critical. Long training experience indicates it is very desirable that the V_{mca} (minimum control speed — airborne) with the two most unfavorable engines inoperative not exceed the approach speed with full flaps.

The 180-lb rudder force at full deflection permitted by CAR is entirely too high. Where rudder forces of this magnitude have existed, the aircraft controllability about all three axes was adversely affected. A recommended maximum force of about 75–100 lb at take-off and landing speeds appears to be satisfactory. In addition, however, the force versus deflection curve should be nonlinear (good centering) to prevent overcontrolling when small deflections are required, and should then smoothly round over to the point of maximum-force-maximum-deflection with no abrupt gradient changes.

Longitudinal Control Requirements

The longitudinal control characteristics of present-day jets are good except for one area: the stabilizer-elevator relationship. Under trimmed or near-trimmed conditions of flight there are no un-

desirable features. But there have been incidents wherein the aircraft was mis-loaded to the point where it would not unstick on take-off with full-up elevator. During one incident it was necessary to ease the elevator pressure and retrim the stabilizer hurriedly while progressing toward the end of the available concrete at some 250 fps. After this hurried retrim, a second unstick attempt was satisfactory.

In a second case a normal liftoff was made. But immediately upon becoming airborne the aircraft assumed a progressively nose-up attitude in spite of corrective force of both pilots on the yoke and stabilizer control. Luckily, the aircraft was light and climbed rapidly. The crew then realized that the stabilizer was trimmed full nose-up, but were unable to retrim it because of the out-of-trim stabilizer-elevator relationship existing. . . . . The instructor (an ex-test pilot) had the presence of mind to cut the thrust to idle, which allowed the nose to drop to the point where they were able to ease the nose-down pressure on the elevator and then retrim the stabilizer. Intensive investigation failed to show how the stabilizer got all the way nose-up. The incident indicates possibly the need for a reappraisal of the elevator-stabilizer design philosophy. We believe that, as a minimum, it should be such that:

1. The elevator can unstick the aircraft with the maximum possible nose-down out-of-trim condition within the allowable take-off setting range and aircraft loadings.

2. The elevator can prevent the aircraft from stalling with the stabilizer trimmed nose up to the limits of the take-off setting range, with allowable aircraft loadings.

   a. The stabilizer should be made such that it can not operate outside the take-off setting range with the airplane on the ground.

3. The elevator can land the aircraft with stabilizer jammed in the most adverse trimmed normal flight condition.

4. The stabilizer actuator system should be sufficiently powerful so that the stabilizer setting can be changed regardless of the out-of-trim condition.

Approach configuration speed stability

"Can an airplane be flown comfortably and precisely on the approach on the "back-side" of the speed-power curve?" Many pilots will argue this subject very emotionally. We should look very carefully again at the simple fundamental requirements involved.

When the pilot wishes to increase his glide slope angle he should be able to ease the nose down and accomplish just this. When he wants to decrease the glide slope angle, he will instinctively raise the nose . . . . and he normally expects the airplane to attain a flatter approach path. If other things happen (such as raising the nose causes a steeper approach angle), we have an obviously intolerable situation which could lead to nothing but disaster.

Similarly, if the pilot wants to increase speed on the approach, an addition of thrust along with the change in angle of attack to maintain the desired glide path should give him the desired result without an accompanying roll, pitch, or marked change in stick forces. Also, if he wants to decrease speed, a simple thrust adjustment should, along with the angle of attack adjustment, take care of this.

In other words, any reverse sensing from the *normal current techniques* that are used in present-day airplanes or unnecessary additional reactions or motions of the aircraft are very undesirable.

The margins between the approach C_l and the maximum C_l as well as the slope of the C_l-alpha curve are very important and cannot be excluded from any considerations of the approach problem. Again, the problem lies in the precision of control, and in the realization that the airline pilot has to put the most advanced transport airplane on the ground in approximately the same dimensions of runway that have been used for many years. He cannot be expected to adapt to new or radically different techniques of handling without prohibitively expensive training programs. This is not to say that the use of stability augmenting devices or other auxiliary devices which repair an adverse characteristic would not be acceptable. The point is that **the pilot is a given entity with a given set of habits and conditioned responses, which are not easily changed and he must essentially be reckoned with in the "as is" configuration!**

Landing Performance Considerations

Approach speeds

It is appropriate to examine closely the experience to date with our latest generation jet aircraft with an eye to the probable magnitude of revised requirements which will apply to the supersonic transport . . . and to any new model yet to be certified.

Threshold speed is important throughout the entire landing because it enters prominently into the margin of controllability of the final approach glide path, the ease of flare, and, after touchdown, the stopping distance. The threshold speed specified in determing landing distance for jets is 1.3 V_s (V_s Airplane stall speed). (This is not a new figure in the regulatory sense, having been a part of CAR since Part 04 was first written, but it is a new figure in the substantive sense, because the margins available to the pilot have changed because of the lack of slipstream, or power on, effects.)

In making an approach at 1.3 V_s with low power

SUPERSONIC transport

. . . continued

settings, whether in a propeller or jet aircraft, a pilot might expect a theoretical excess of lift of 69% if he made use of the maximum lift coefficient. Actually, the jet transports as currently certified have an excess of lift at 1.3 V_s speeds of between 45 and 65%, depending on the model. However, in the case of a propeller aircraft, not only can the theoretical maximum lift be obtained by a more moderate change in angle of attack, but the new theoretical maximum, with 100% power, now becomes 142% of the 1.3 V_s lift. This is better than double the theoretical margin available to the jet pilot.

What is the practical margin?

We can reasonably conclude from pilot experience that 1.3 V_s *as currently defined* in the regulations is not an adequate speed margin under all operating conditions. However, we do know that, when we fly airplanes at speeds such as 70–80% excess lift is available actually during the approach and flare, we do in general, have a satisfactorily responding airplane, as far as precise glide path control, flare, and touchdown are concerned.

To remedy this there are two possible alternative solutions:

1. Increase the threshold speed to some value above 1.3 V_s.
2. Increase the actual available lift between 1.3 V_s and V_s by redefining the stall speed to reflect a practical and usable minimum level flight speed.

If method (1) were chosen we would intuitively pick a value for threshold speed of about 1.3 V_s + 10 knots to give adequate glide path control in the final approach phase and adequate margin during the flare for gusts, wind, and shear. However, this would lengthen the landing distances about 15%, which is probably unattractive.

Method (2) would, in effect, provide the same flare margin with the important exception that it would provide the designer with latitude to make aerodynamic improvements so that the threshold speed would not have to be increased.

It is our opinion that the most practical way to obtain this additional C_l or lift margin is to define V_s for the landing configuration as the minimum theoretical speed where the airplane could be flown steadily in level flight without the lifting effects of thrust. This criterion should establish a speed where the airplane wing would have the full measure of additional lift corresponding to the 30% airspeed increment over the minimum safe flyable speed.

Landing distance

As regards stopping distance, we have essentially the same certification rules for piston and jet aircraft. Yet, the numbers come out quite differently. This change was caused by the use of antiskid brakes and spoilers on the jets, which, together, permit much more effective braking action on the specified "smooth, dry, hard-surfaced runway" than formerly.

The result of the more effective braking action is that, for a given approach speed, 1.3 V_s, the stopping distances and CAR landing distances are appreciably shorter for the jets than for the props. This fact prompted F. W. Kolk to write in an October 1959 SAE paper: ". . . the certificated landing distances for intended destination of jet aircraft were unconservatively short for airline operation. . . . Operational evaluation has indicated that the practical landing runway is, in truth, some 15–20% in excess of the certificated values." Kolk suggests as a lower limit for field length requirements for the current jet aircraft the empirical value:

$$D = \frac{V^2}{2.9} + 390$$

where:

D = Runway required, ft
V = Threshold speed, knots

This, we believe, is an expression of the *status quo* rather than a desired criterion. Preview of some personal experiences with landings on various airports throughout the world under various adverse conditions tends to verify the above relationship for present jet aircraft. So exactly where is the shortcoming of the present landing field length criterion?

We think that Kolk as well as ourselves would have no complaint regarding landing distances if the stopping capability on the wet and icy runways were greater. The propeller airplane, with reversing, possessed a large margin of stopping capability on runways where braking coefficients were poor. Consequently, it appears that the problem is one of maintaining a suitable balance between the stopping capabilities with and without wheel brakes.

So, we believe designers should restore and maintain an adequate balance between the dry runway and the slippery runway stopping capabilities. A criterion that would express this balance might go something like this:

The CAR landing field length (as established on dry concrete) should at least equal the ground roll stopping distance without wheel brakes.

Since there always is some wheel braking effectiveness, even on ice, it is believed that this criterion would be optionally acceptable. Possibly, the no wheel brake stopping distance should make some allowance for the touchdown point being approximately 1000 ft from the approach end of the runway. In any event, a criterion of this sort would place more design emphasis on the stopping capability on poor runway conditions; this is the missing link in the current design goals, in our opinion.

To Order Paper No. 341B . . .
from which material for this article was drawn, see p. 6.

New Knock Testing Methods
Needed to Match Fuel-Engine Progress

Based on paper by

Earl Bartholomew

Research & Development Department, Ethyl Corp.

EARL BARTHOLOMEW has earned a place among the automotive industry's distinguished elder statesmen in the field of fuel-engine relationships. His call for new knock test methods, in this article, warrants unusual attention because of his personal participation in knock test problems for more than a quarter of a century.

Bartholomew was a pioneer in the development of equipment and techniques for measuring the antiknock testing of gasolines. As far back as 1927, he participated in the development and building of the first standardized knock testing engines and the equipment associated with them.

In the years since, he has made periodic contributions to technical literature related to this research field. Among these were his 1938 SAE paper, "Carburetion, Manifolding, and Fuel Antiknock Value" — which was co-authored by H. J. Chalk and B. Brewster . . . and his 1946 SAE paper, "Potentialities of the New Fuels in Design of Passenger-Car Engines."

These two earlier papers contributed to an understanding of engine and fuel developments that have created a need for the new antiknock methods urged in this article.

Before entering the automotive field, Bartholomew had been an instructor in mechanical engineering at the University of Oklahoma and at Harvard University. Since joining Ethyl Corp. in 1926, he has actively directed fundamental studies on mutual adaptation of engines and fuels — with particular emphasis on the benefits and problems associated with increased compression.

A CHALLENGE is presented to the people of the automotive and petroleum industries to utilize their diverse talents and to apply their accumulated experience in developing new knock testing methods that will truly reflect the tremendous advances in automobile design and gasoline refining that occurred in the Thirties, Forties and, Fifties. Achievement of combustion environments of automobile engines within the cylinder of a knock testing engine will require collective organization of the experimental efforts of many individual laboratories. Equally important will be presentation and consideration of analyses and proposals from individual laboratories, such as those contained in the 1958 paper by Siegel.[1]

Previously demonstrated competence should also be able to develop a sensitive instrument capable of reproducible measurement of knocking and with response parallel to that of the human ear. Mechanical ingenuity such as that which created automatic transmissions should be able to devise an arrangement whereby the test engine could be shifted instantaneously from conventional intake manifold to one with modification designed to simulate the effect of fuel lag in the manifolds of automobiles.

Old methods no longer satisfactory

The Research and Motor knock testing methods very satisfactorily met the requirements existing at the time of their development — 30 years ago. Since then, refining technologists have learned how to pull apart the molecules of petroleum and to recombine the carbon and hydrogen atoms into almost any desired pattern. The chemical complexity of modern gasolines reflects this breakthrough. In turn, the widened range of chemical composition has enhanced the utility of antiknock compounds and made commercially feasible a variety of new ones.

During the same period, automotive engineers have succeeded in producing almost two and one-half times as much power per cubic inch of engine displacement. At speeds attainable in car engines of three decades ago only under runaway operation, modern engines develop torque equal to the maxi-

[1] "Use of Temperature-Density for Measuring Antiknock Quality," Bruno R. Siegel. SAE Transactions, Vol. 66, 1958, pp. 421–443.

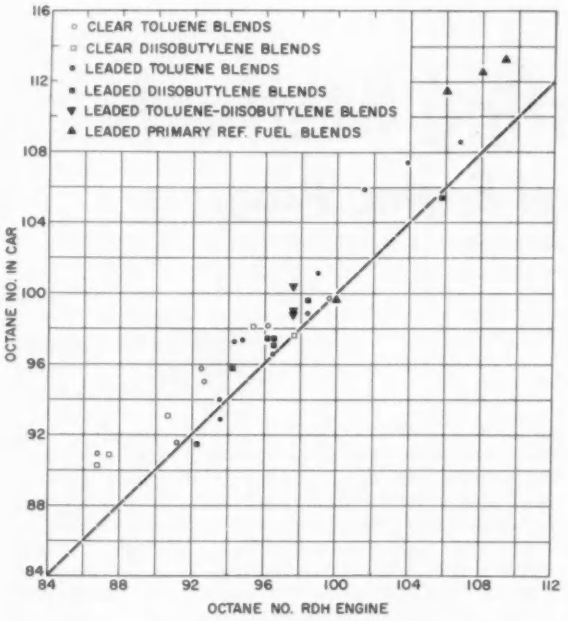


Fig. 1 — Correlation of car and laboratory octane numbers. Car engine: ES-59, 12/1 compression ratio, 3500 rpm; laboratory engine: RDH, 2400 rpm.

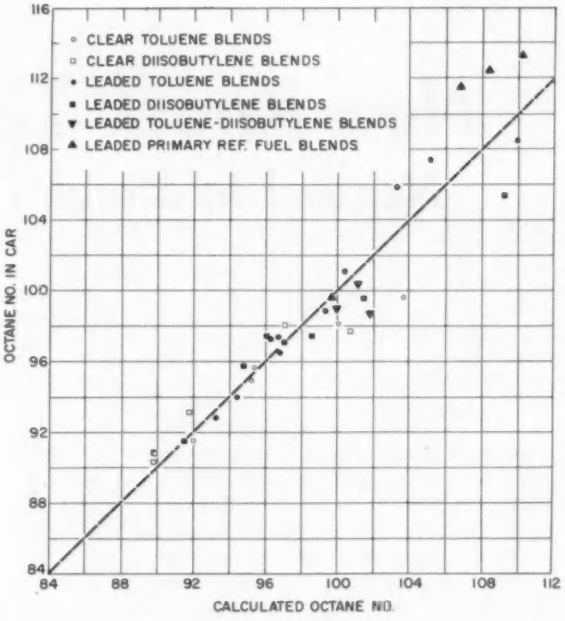


Fig. 2 — Correlation of car and calculated octane numbers. Car engine: ES-59, 12/1 compression ratio, 3500 rpm; calc. ON = 0.42 ON (in RDH at 600 rpm) + 0.58 ON (in RDH at 2400 rpm).

New Knock Testing Methods

. . . continued

mum of the early engines. As a consequence, the range of speed within which knocking now occurs is several times as broad.

A different "high-speed" test method

The greatest present need is thus, for a test method capable of predicting accurately fuel ratings to be expected in automobiles at high engine speeds. The method should completely realign gasolines on the quality scale relative to the positions assigned by the Research or Motor method. To accomplish its intended purpose, an improved "high-speed" test method must:

1. Substantially duplicate Motor-method ratings of paraffinic fuels containing lead.
2. Assign higher ratings to lead-treated highly aromatic fuels than to lead-treated olefinic fuels having the same difference between Research and Motor ratings.

The effects on diverse types of fuels resulting from an increase in temperature of fuel-air mixture or cooling liquid are not parallel to those accompanying an increase in speed. Boost of temperature depreciates fuels somewhat in proportion to the difference between their Research and Motor ratings, whether the fuels are clear or lead-treated. Increase in speed alters the ratings of lead-treated fuels in accordance with a pattern that bears no relation to sensitivity. Where the difference between Research and Motor ratings is large, increase in the speed of car engines substantially *lowers* the ratings of highly olefinic lead-treated fuels. In contrast, the ratings of highly aromatic fuels containing lead may remain constant or even *rise* with increase of speed.

We have not yet found a method for producing ratings on single-cylinder engines that correlate with gasoline behavior in automobile engines at high speed except by operation of test engines at considerably higher than conventional speeds. Future research may disclose other means for achieving the desired result.

Because of encouraging results obtained on other single-cylinder engines at higher rotative speed, it appeared desirable to ascertain the directional effect of an increase in the speed of the RDH engine (which incorporates the CFR high-speed crankcase and a new cylinder with removable head having a crescent-shaped combustion chamber) above the levels conventionally employed for knock testing engines. The selected conditions of operation were:

a. Speed, 2400 rpm
b. Jacket temperature, 190 F.
c. Air pressure at intake port, 30 in. Hg absolute.
d. Air inlet temperature, 100 F.
e. Mixture ratio for sample and reference fuels, maximum knock.
f. Ignition timing for best power.
g. Compression ratio for incipient knock as detected aurally.

Thirty-five fuels, selected for their diverse chemical composition, were rated in a car with a GM ES-59 experimental V-8 high compression engine at 12/1 compression ratio and 3500 rpm. These octane numbers are plotted in Fig. 1 against ratings obtained in the RDH engine under the conditions just described. Obviously the operating conditions for the RDH engine resulted in somewhat greater severity than those of the car engine at 3500 rpm. The average of the ratings in the car was 1.8 octane units above the RDH ratings. In general the octane numbers of the fuels in the car engine at 3500 rpm were below the ratings in the RDH engine at 600 rpm. This illustrates the necessity of two knock testing methods.

The average of the ratings of the 35 fuels in the car engine at 3500 rpm is the same as the average of ratings computed by use of the equation:

Calc. ON = 0.42 ON (in RDH at 600 rpm) + 0.58 ON (in RDH at 2400 rpm)

In Fig. 2 the ratings in the car engine at 3500 rpm are plotted against the computed ratings. Below 102 octane number the correlation is good, in view of the small number of ratings on each fuel. It is not known whether the scatter of data points at higher antiknock levels is caused by failure to duplicate the combustion environment of the car engine in the RDH engine or to the difficulty of detecting knock aurally at high compression ratios and high engine speeds.

The favorable experience with the RDH engine justifies the hope that engine modifications and operational procedures will be found that will provide ratings closely correlated with the performance of all types of fuels in automobiles operated at either low or high engine speeds.

Benefits of new ratings

SUCCESSFUL development of new knock testing methods, the author declares, would have tremendous value by lending practical significance to gasoline specifications based on laboratory antiknock ratings. Car manufacturers, oil refiners, and motorists would benefit. Satisfactory new methods would constitute a major technical breakthrough for the Sixties.

Moreover, the economic stakes are high. Because of the extensive background now available, the cost of the development program should be small compared to that of creating the Research and Motor methods.

Relative to gasoline sales, the cost would be even smaller, since only 15 billion gallons were used in 1930, compared to the present annual volume of 60 billion gallons. The development cost should be offset quickly by savings resulting from simplified procedures and more significant ratings.

A laboratory "part-throttle" method

Ratings of clear and leaded toluene-containing fuels in the car engine at part throttle are lower than full-throttle ratings. In view of the difference in conditions within the cylinders at the two operating conditions, the difference in ratings is not surprising.

Some alteration of the full-throttle operating conditions of the test engine will be required for indication of fuel performance to be expected in automobile engines at part throttle. One fuel, which contained 40% toluene, had higher than Research ratings at part throttle when speed was above 2000 rpm. Mixture heating causes the ratings of both clear and leaded fuels containing a substantial amount of aromatics to fall below their Research ratings. Accordingly, it seems likely that some other change in operating conditions will be required. The most logical would appear to be throttling of the carburetor of the test engine.

Possible effect of knock-measuring instrument

Some part of the difference between ratings by Research and Motor methods and those obtained in the RDH engine may be due to deviation of the response of the conventional knockmeter from that of the human ear. Efforts have been made to rate fuels in the CFR engine under Research and Motor conditions except for detection of knock by ear instead of the knockmeter. Variability of the latter ratings has been so high that reliable conclusions could not be reached concerning deviations ascribable to method of knock detection. The listening method may be employed on the RDH engine, but the cylinder head is not machined to receive the present D-1 knockmeter pickup. Accordingly, direct comparisons of detection methods could not be made.

Mechanical noise in single-cylinder engines during the whole cycle of operation adds to the difficulty of aural detection of knock. (A considerable amount of such noise is also present in automobile engines, but much of it is filtered out by the car body and does not reach the passengers.) At quite high compression ratios, differentiation of incipient knock from the noise due to the rapid rise of pressure associated with normal combustion becomes less certain. For these reasons few operators are likely to achieve in aural measurements the degree of reproducibility associated with a good instrument. Moreover the fatigue factor and interference from the other test engines nearby eliminate the alternative of audible measurement of knock in routine operations. Electronic instruments can be designed to be responsive only during the small fraction of the cycle when the end gas burns and knocking occurs. Fortunately, during this period, the noise of engine components is at a minimum.

The original bouncing-pin indicator responded to rate of pressure rise. A requirement imposed on the development of the present detonation-measuring instrument was duplication of the performance of

New Knock Testing Methods

. . . continued

the bouncing-pin indicator. As a consequence the present instrument likewise responds to rate of pressure rise.

The external noise associated with knocking in the cylinder appears to be the response of the engine structure to a high-impulse pressure wave generated by knocking. The frequency is between 6000 and 8000 cps. Some research projects have indicated correlation of audible knock intensity with amplitude of the high-impulse pressure wave in the cylinder. As background for the development of an improved instrument, a great need exists for careful recording and analysis of the sound of knocking as heard near engines and in automobiles. It should be determined whether the composition of the sound for all types of fuels is the same at the two locations.

Possibly, an instrument would be acceptable that would indicate the amplitude of either the high-impulse pressure wave in the cylinder or of the sound wave in the external air. Each approach would have its advantages and disadvantages. Alternatively, the peaks of the waves might be clipped and their frequency of occurrence measured. Absolute correlation of rate of pressure rise with either of these manifestations of knocking should not be assumed. It is gratifying to note that several laboratories are engaged in experimentation directed toward development of improved knock-measuring instruments and that progress apparently is being made.

Simulation of fuel lag in manifold

Discussion up to this point has been concerned with engine operation on fuels whose volatility was such that fuel lag in the manifold during acceleration was insignificant. During full-throttle acceleration of an average automobile using an *average* gasoline, only partial vaporization occurs.

When ratings obtained in automobiles are compared with ratings of the whole fuels made by the Research and Motor methods, the appreciation or depreciation on the road is a combination of:

1. That due to differences in severity of the car and laboratory engines.
2. That arising from lag of heavy ends of fuels in the manifold.

If an effort is made to obtain the same total appreciation or depreciation in the laboratory engine as in automobiles by adjustment of temperature or speed, correlation of the two types of ratings is certain to be poor. No consistent relation exists between distribution of antiknock quality over the distillation range and sensitivity of fuels to temperature and speed.

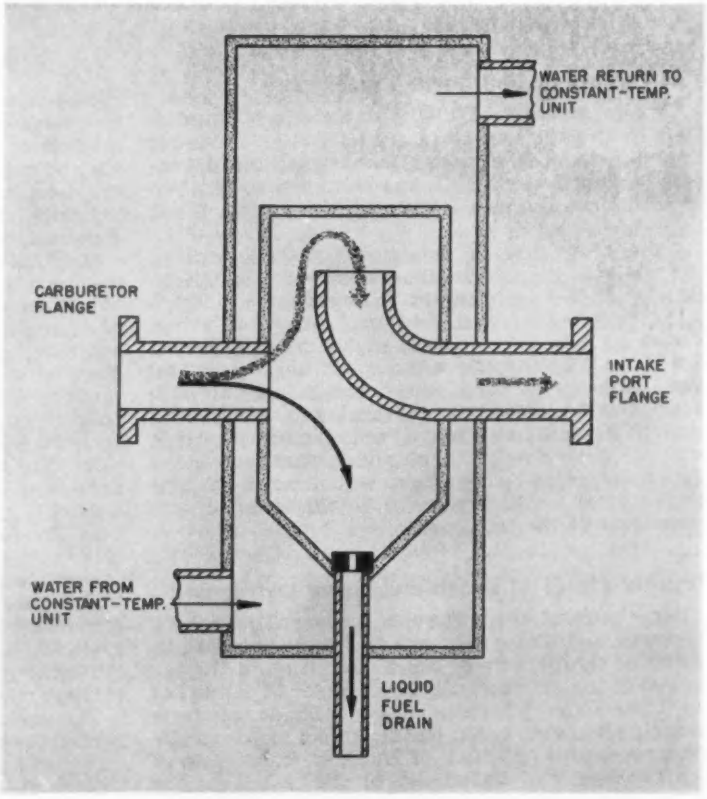


Fig. 3 — Improved "bled" manifold.

Adjustment of laboratory ratings for the effect of fuel lag in the manifold requires recognition of any difference between the antiknock quality of the front part of the fuel and that of the whole fuel. Long ago it was found that cutting a fuel in a pot-type still at some temperature less than the end point and measuring the Research octane number of the distillate by the Research method provided a better indication of the performance of gasolines in automobiles during low-speed acceleration where separation of heavy ends occurs. Such a procedure is time consuming, however, and expensive for routine use.

A much less complicated and expensive procedure was developed many years ago. A special manifold for the CFR engine included a trap in which heavy ends of fuels were separated for drainage from the manifold.

More recently, the same principle was incorporated in a more simple and convenient unit (Fig. 3). Variation in the percentage of heavy ends separated is obtained by adjustment of the temperature of an external electrically heated constant-temperature bath, which includes a pump for circulating the heated water through the jacket of the manifold.

A single setting of the temperature of the external bath establishes for all fuels, conditions in the special manifold that simulate those in the manifold of a particular car. Depending on their volatility, widely different amounts of base fuels and antiknock compounds may be trapped and drained from the manifold at constant jacket temperature. Likewise, different percentages of the gasolines are retained in the manifolds of cars during low-speed acceleration.

Figs. 4 and 5 illustrate the improvement that was accomplished in a correlation of laboratory ratings with those obtained at 1500 rpm in a car equipped with an automatic transmission. Fig. 4 compares the car and Research ratings of 20 full-boiling fuels specially blended to vary the placement of saturates, aromatics, and olefins within the distillation range. The maximum difference in Research ratings is only a little more than one octane unit. Road ratings are fairly evenly distributed over a wide range, only 5 being within ± 1 octane unit of the line of perfect correlation. The deviations of the road ratings bear no relation to sensitivity of the fuels.

Fig. 5 compares the road ratings of the fuels of Fig. 4 with ratings obtained on a Research engine equipped with the manifold of Fig. 3 operated at a jacket temperature of 105 F. Now the ratings of 17 of the 20 fuels are within ± 1 octane unit of the line of perfect correlation. Conditions within the knocking cylinder of the car engine apparently were a little more severe than in the Research engine, inasmuch as a slight increase in the severity of the laboratory engine equipped with the special manifold brought an even better approach to correlation with car ratings. Obviously, however, the largest factor by far contributing to difference between road and Research ratings was failure of the Research method to recognize separation of heavy ends of the fuels in the manifold of the car engine.

In the light of manifold effects indicated in Figs. 4 and 5, it can be speculated that even larger effects may occur in automobiles with manual transmissions, where the speed of maximum knock is near 800 rpm. Experience has confirmed the suspicion. The advantage of tml over tel in such automobiles, because of its better volatility, may be as much as five octane units. The only possible method of reflecting this advantage in laboratory knock ratings is through some modification of procedure which eliminates heavy ends of fuels from the evaluation.

To Order Paper No. 285A . . .
from which material for this article was drawn, see p. 6.

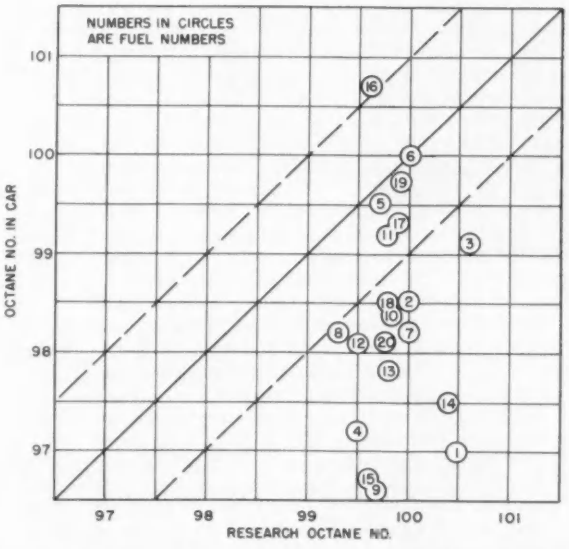


Fig. 4 — Correlation of car and Research octane numbers. 1956 car with automatic transmission, 11.3/1 compression ratio, 1500 rpm. 20 full-boiling gasolines.

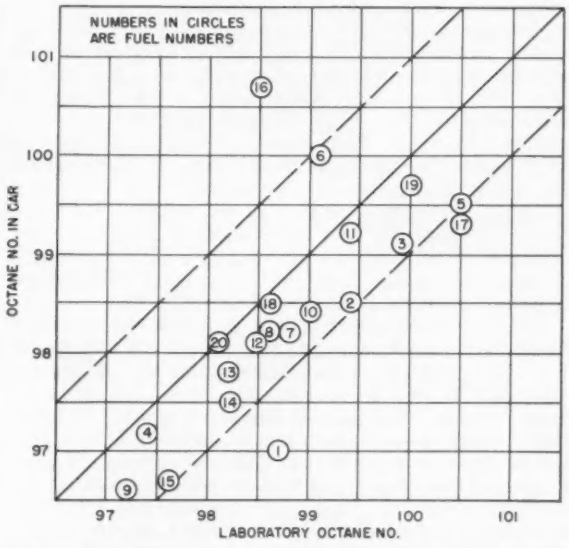


Fig. 5 — Correlation of car and laboratory octane numbers. 1956 car with automatic transmission, 11.3/1 compression ratio, 1500 rpm. Laboratory engine: CFR engine equipped with "bled" manifold, Research-method conditions. 20 full-boiling gasolines.

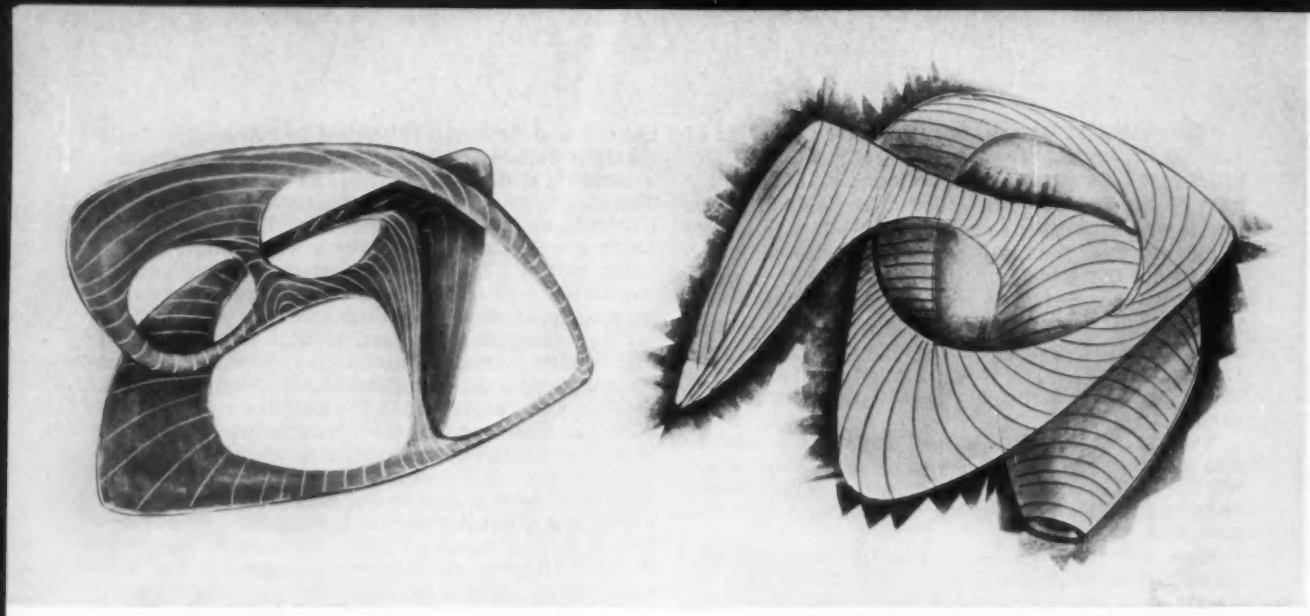


Fig. 1 — Re-entrant curves and convolutions

coming: Plastics' breakthrough in

Based on paper by

Robert T. Stevens, Irwin J. Gusman and Irving B. Cohen

J. P. Stevens & Co.

NEW DESIGN, engineering, and processing techniques will evolve, not too many years from now, which will allow the automotive industry to take full advantage of the spiraling technological progress of high-strength structural plastics.

New shapes, convolutions, and re-entrant curves will be available for the auto bodies of the future (Fig. 1). These will be ingeniously designed and more readily fabricated by new breakthroughs in molded plastics. Manufacturing teams will work with large, lightweight, high-strength body shells formed in large molds at high speeds. Revolutionary bonding techniques will replace joining methods currently used for the multipart steel body. The number of joints will be reduced by combining many components in one mold. This, in turn, will reduce costs and provide cleaner exterior esthetics.

Functional integration will be achieved through simplified monocoque or shell-type constructions featuring little or no separate framing. Strength and rigidity will be molded in. The roof and the head liner will be one and the same piece. Interior trim and styling will be part of the body shell. The trunk, gas tank, and spare-tire well may be one molding. The floor pan will be combined with the covering material. The instrument panel, fire wall, and plenum chamber will be molded as one piece. Where acoustical and thermal insulation is needed, polyether-based urethane foams may be sprayed onto the plastic shell and become an integral part of it. The doors will be of sandwich construction, with prepossessing plastic facings supported by high-strength plastic honeycomb structures in between (Fig. 2).

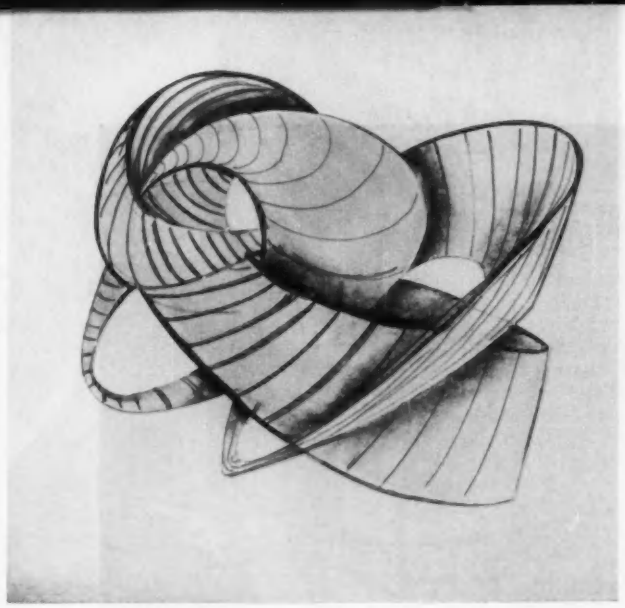
Shell-type construction will make possible increased interior space while the outer envelope is decreased (without reducing engine size or occupant capacity). The plastics body structure will result in a durable compact car with far greater maneuverability and flexibility available to the ingenious body engineer (Fig. 3). Lower tooling costs will accompany the use of structural plastics. Minor functional body changes will be made during the model year at relatively little cost. And, tooling economies will open new opportunities for the multi-purpose body concept — a greater number of body types available to meet the ever-changing and ever-increasing demands of the consumer and the industrial user.

Reinforced plastics will permit the auto industry to cross wide boundaries in engineering practice and accelerate the use of new power generators and new overall manufacturing concepts, with resulting improvements in personal transportation and increased safety, comfort, styling, and economy.

Because there are superior qualities of compatibility inherent in reinforced plastics with the dream car of tomorrow, let's look at some of the possibilities that exist for tomorrow's vehicles.

Flotation Systems — These are likely to be important in vehicles of the future, and need not be appendages, since they can be built into the body through the use of sprayed-on foam sandwiches. Likewise, they readily could be interposed as enclosed pores or honeycombs in the integral body-shell material.

Air Foils — In smooth-flowing designs and easily maintained polished surfaces, these will be needed and available in the vanguard of prospective devel-



possible in plastics.

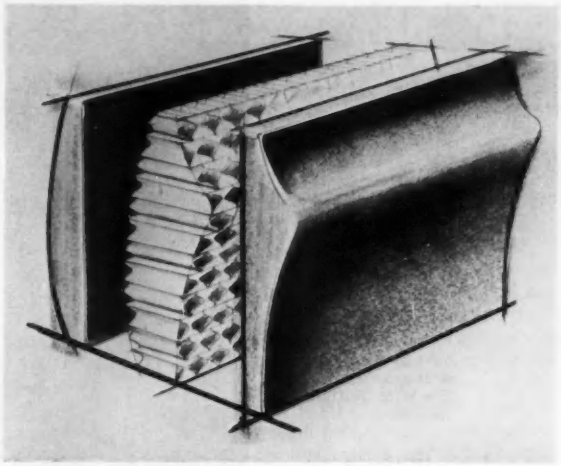


Fig. 2 — Tomorrow's car doors are expected to be of sandwich construction — plastic facings supported by high-strength plastic honeycomb.

auto bodies

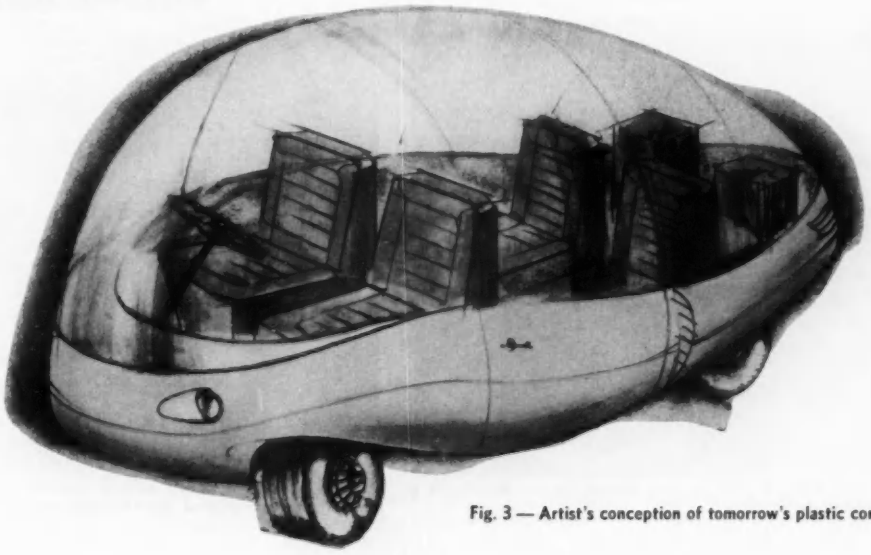


Fig. 3 — Artist's conception of tomorrow's plastic compact car.

opments in the chemistry of low-density, high-strength, esthetic plastics.

Uniwheel Car — This car is realistically predictable (Fig. 4). Lightweight functional design is essential in the uniwheel, since it will be held upright by gyroscopic devices. In this car, lightweight reinforced plastic materials also will help to facilitate maneuverability and efficiency. This gyro-car, operating on a single massive tire, also must be built for maximum strength to support the electronic gear which most future cars are likely to contain. The tire, with a projected tread life of 200,000 miles, might be cast from a liquid resin resulting from a chemical reaction between a polyether glycol and a polyisocyanate, reinforced with a two-phased glass fiber, and have a tread-coating of a fluorocarbon.

New Types of Power Systems — These systems seldom will require replacement or refueling, and will be highly efficient in energy conversion and weight factors. Several of these avant-garde power systems have been in the forefront of automotive research for some time. They include the fuel cell, the solar battery, the gas turbine, the thermionic converter, nuclear energy, solid fuels, and even the plasma jet source.

The Fuel Cell — It would appear feasible to inte-

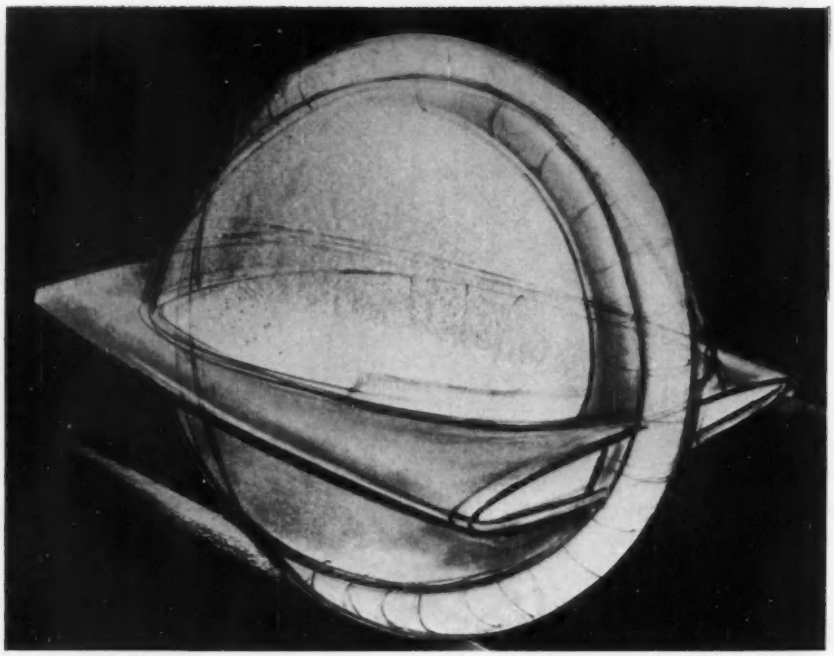


Fig. 4 — Uniwheel plastic car will be held upright by gyroscopic devices and feature a single tire with 200,000 mile tread life.

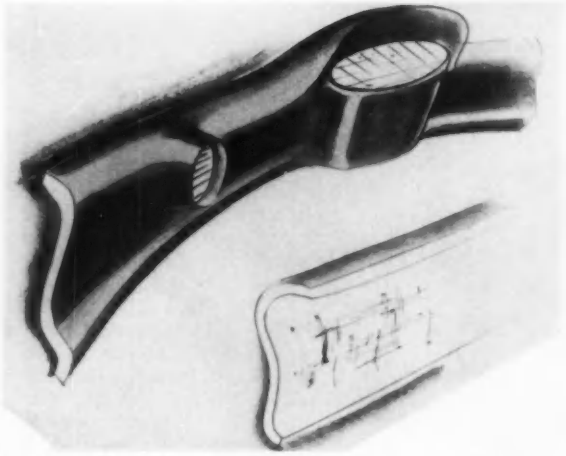


Fig. 5 — Plastic dashboard will feature painted on printed circuit to handle electrical requirements.

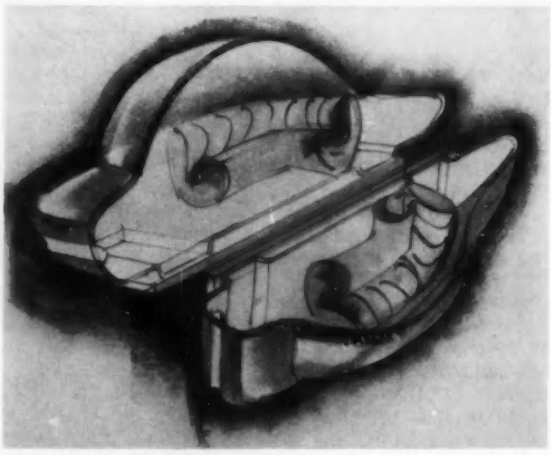


Fig. 6 — Two-piece plastic molded assembly will permit integration of exhaust, spring, electrical, and hydraulic systems.

Plastics' breakthrough in auto bodies

. . . continued

grate fuel cells into a plastic body structure through compartments molded into the shells during fabrication. If power units are used for each wheel, it would be easy to design and place the needed power cell compartments where needed. The durability of reinforced plastic, with its inertness to electrical and chemical influences, favors this type of body structure for all new propulsion concepts now in the research laboratories or blueprinted for future development.

Advanced Manufacturing Techniques — In tomorrow's body designs of reinforced plastics, it will be possible to greatly reduce the number of pieces necessary in the body. It will be possible to combine

parts with the body shell — functional components — which previously had to be hung on further down the assembly line. The unusual strength and heat-resistant properties of reinforced plastics even suggest that it will be possible to integrate the entire exhaust system (if needed), including mufflers, into the body. These might be composed of glass fibers or fibers of advanced heat-resistant substances, such as titanium salts, consolidated into the plastic matrix. Thus, the reinforced plastics for the exhaust system would differ only slightly from those used in the rest of the body. However, the present exhaust and muffler systems may be eliminated entirely in the more advanced powerplants now under study. If they do continue in future use, the noncorroding nature of these reinforced plastic materials, even at elevated temperatures, should make them especially well suited for these systems. There are further advances coming from the ceramics industry in the form of glass fibers, that will sustain exposure to even higher temperatures, and thus resist attack from even more severe environments than is conceivable today.

Spring Torsion-Bar System — This probably will become an integral part of the body, since the strength and elastic properties of glass fiber-reinforced plastic materials have made possible such highly stressed applications as springs.

The implications of unitizing or integrating many components or systems into a single body is important for many reasons. One of the most attractive values would be the opportunity for readily automating the assembly line; indeed, even computer-controlling it. Picture a body shell of reinforced plastic moving down an assembly line, with spring and exhaust systems already fabricated into the structure (in the initial mechanized molding operation). The electrical system could then be added, not by hanging on a multitude of harnesses, wiring systems, relays, and the like, but rather, by means of a printed circuit which would automatically be painted onto the plastic body structure (Fig. 5). In addition to the printed circuit, it is conceivable that certain other advances could result not only in the distribution of electrical power through the body, but also accomplish the function of electromechanical generators, relays, and other circuit devices. These functions also might be carried out as solid-state reactions within materials molded into the plastic body.

The maintenance and repair of such ingenious circuitry, when needed, could be uncomplicated, since it would be easy to delete the entire circuit, and in effect reprint or reinstall a new one.

Further integration could be accomplished by molding into the body shell the ducts for conveying fuel, heating and cooling fluids, and oil for the central hydraulic system. The hydraulic system would activate windows, seats, trunk lid, engine hood, brakes, and transmission. If our futuristic car contains one fluid for cooling, braking, steering, and other power functions, the single master fluid will undoubtedly be sealed into a plastic unit molded into the body structure. This duct work could be accomplished by preforming certain tubes into the structure or bonding small hat sections along the inner surface of the plastic shell. These ducts also would provide greater rigidity to the shell.

Thus, it may be possible that the body, when it reaches the end of the assembly line, has integrated in it (rather than hung on to it) the exhaust and spring systems, the electrical system, and the ducts needed to transfer air and fluids to any location in the car. Because these systems are molded into the car body, without mechanical joints, they never should leak or shake apart (Fig. 6).

It is also conceivable that color and surface finish can be impregnated into the reinforced plastic material during the molding of the body shell. Waxlike impregnations might be chemically devised to migrate gradually to the surface and provide the car with a perpetually attractive finish.

In the area of esthetics, certain built-in lighting effects could be accomplished for day or night. It appears possible to style a highly fashionable, per-

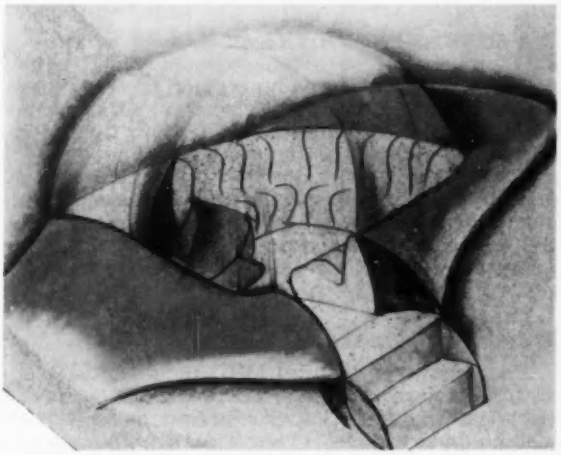


Fig. 7 — One-piece plastic skylight car may feature bubble-top which could be semitransparent, translucent, or opaque. Polarization would control the admittance of light.

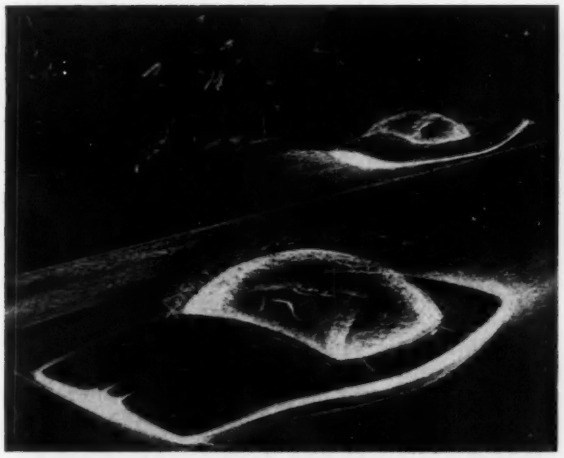


Fig. 8 — Interesting lighting effects may be produced by electroluminescence of certain plastic materials.

Plastics' breakthrough in auto bodies

. . . continued

manent bubble-top, which could be either semi-transparent, translucent, or completely opaque by controlling the polarization of light that would otherwise be admitted (Fig. 7). Another possibility might be found in the work being done with photo-tropic materials. The phototropic material would contain a solid dispersed in plastic to keep the amount of light entering the car under complete control. It would work whether dealing with sunlight, or glare from normal night driving when bright headlights fall upon it.

It should be possible to provide the future car owner with a selection of body colors by conducting colored lighting effects through the outer skin of the plastic body. This scheme would utilize the capabilities of certain plastic materials to conduct light or provide a path for it. By the same principle, light could be conducted to protruding panels or knobs which would act as headlights and taillights.

Other interesting lighting effects could be accomplished not only by light conduction, diffusion, panel-glowing, and light bars, but also by electroluminescence of certain plastic materials containing the proper excitable salts. Phosphorescent, reflectant, and fluorescent materials could be added to the plastic body material for further styling and identification purposes (Fig. 8). The lighting potentials of plastic auto bodies provide the engineer with opportunities for inventiveness and styling creativity never before possible in bodies of other materials. These opportunities apply equally to internal and external lighting systems.

Since the cars of the future will have facilities for full control of air-conditioning within the car, and adequate means for signaling and traffic control outside, it no longer may be necessary to have windows that open and close. Interspersed or alternate body-panel sections may be used to allow adjustable breathability through selectively permeable cellular structures, which would permit the transfer of air into or out of the car on command. The windows of the car then may be cast into the dome structure during its forming.

In the future, it might be possible to use plastic cellular structures in the outer body shell, as a reservoir for the cooling system fluids and as a heat exchanger.

The rapidly advancing electronic sciences may be useful in the regulation of future automobile traffic. The automotive industry has considered the possibility of electronic systems maintaining contact with guidance control cars in congested areas and on superhighways. Plastic autos, transparent to radar or magnetic contact, may be operated by a driver who will be either constantly guided or even controlled by these electronic signals. As computers become smaller, they could be installed in vehicles and programmed to indicate routes least likely to be congested at any specific time.

To Order Paper No. 274A . . .
from which material for this article was drawn, see p. 6.

No Clutch No Transmission No Brakes

Based on paper by
M. C. Gourdine
Plasmadyne Corp.

MAGNETOHYDRODYNAMICS could be used to propel a car. The vehicle would run on regular gasoline, and would need no ignition system, clutch, transmission, differential, or brakes. This development is not just around the corner, but it is an intriguing possibility for the future.

A MHD motor-generator would provide individual drive to all four wheels. Braking would be accomplished by reducing the fuel supply or by throwing the entire drive into reverse. If combustion were incomplete, an MHD afterburner might prove practical for smog suppression.

Working principles

A schematic of such an MHD reciprocating generator is shown in Fig. 1. There is a piston having electrical conductivity inside a rectangular channel whose upper walls are electrical conductors and whose side walls are insulators. The ends of the channel have an inlet valve (a) and an exhaust valve (b). The device is in a uniform magnetic field of strength (B) directed normal to the insulating walls. In operation, a fuel-air mixture is introduced into both chambers, and a large current through the piston (provided by a starting battery) causes the piston to move to the right until compression ignites the fuel. The piston then moves to the left, compressing and heating the mixture in the left chamber until it also ignites. Then the piston oscillates back and forth through the magnetic field. An alternating emf is generated between the top and bottom electrodes as the piston oscillates, and an a-c current flows in the load.

There is always a retarding force on the piston (Lorentz force) as it oscillates in the field so the gas does work on the piston as it expands, and the piston does work on the external load. Eventually, the

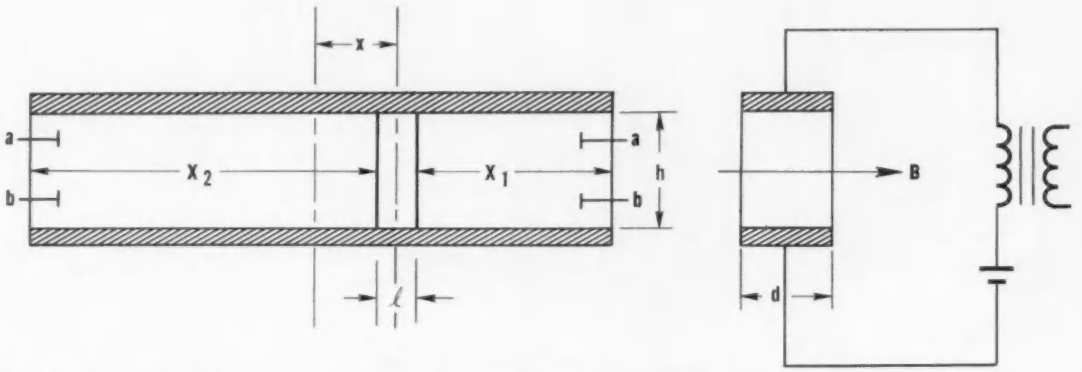


Fig. 1 — Schematic of an MDH reciprocating generator. Efficiency and simplicity are features recommending its development for vehicle propulsion.

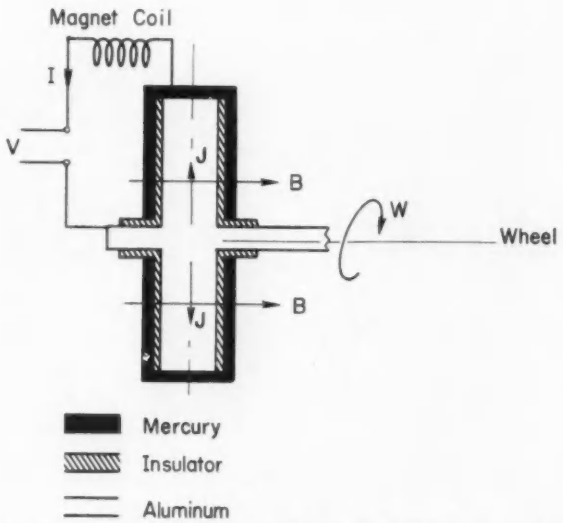


Fig. 2 — Series-wound MHD motor suitable for driving one wheel of an automobile. With individual, four-wheel drive, the motor-generator could also be used for braking and do away with orthodox brakes.

oscillation dies out and the gas has lost energy to the load. Some of the energy of combustion remains in the gas as heat, therefore, the efficiency is less than 100%.

This simple operating procedure can be repeated over and over by timing the input and exhaust valves as in the reciprocating automobile engine. A bank of four or more chambers could be connected in series or in parallel for high voltage or high current loads, respectively.

Individual wheel motors

An MHD motor suitable for driving one wheel is shown in Fig. 2. A liquid metal transferring momentum to radial vanes could be used, but a solid armature will suffice. A solid metal disc attached to the axle is floating in mercury, which acts as brushes for the motor, and also reduces friction losses. The voltage (V) from the reciprocating MHD generator is applied between the central and peripheral electrodes, causing a radial current density (J) in the metal. The Lorentz body-force ($J \times B$) turns the armature and the axle. The torque on the wheel equals the net torque on the armature due to the Lorentz body-force.

Braking action

Reducing the fuel to the generator reduces the output voltage in the generator and the current in the motor. This in turn reduces the Lorentz torque on the wheels, allowing the car to slow down with wind resistance. If the fuel is reduced enough, the motor begins to act as the generator, due to its back emf. It sends a current through the piston, which drives it back and forth in the compressed gas. Thus, the motor-generator acts as a brake because the kinetic energy of the car is changed into thermal energy of the gas in the generator chambers. There may even be a practical method of converting some of this thermal energy back into useful work so that the MHD motor-generator would become very efficient in start-and-stop traffic.

It seems characteristic of MHD equipment that all components are low-voltage, high-current devices. There will be special problems in the field of magnetic design, cooling and heat transfer, strength of materials, as well as stability and control. The rotating armatures of the motors, for instance, may present a difficult problem in gyroscope dynamics. But if the advantages are as attractive as they appear to be, determined efforts to conquer the difficulties are warranted.

To Order Paper No. 312C . . .
from which material for this article was drawn, see p. 6.

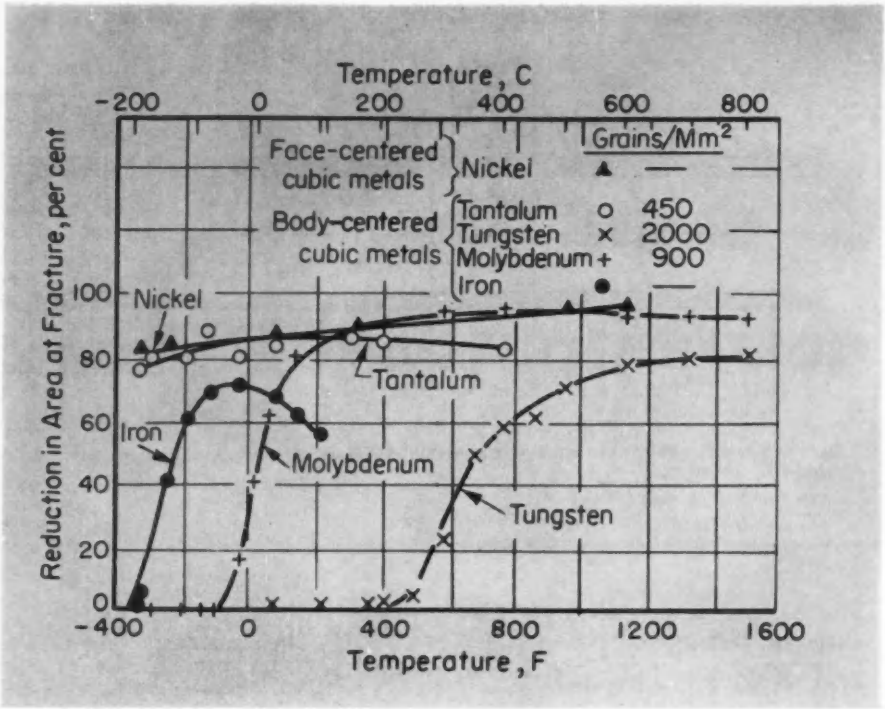


Fig. 1 — Effect of temperature on ductility of cubic metals.

Joining refractory metals is tricky business

Based on paper by

G. M. Slaughter

Oak Ridge National Laboratory

JOINING of the refractory metals and beryllium is considerably more difficult than the common materials of construction.

Special considerations in the welding and brazing of these metals include: transition temperature; reactivity with impurities; recrystallization of parent material; porosity in welds; and intermetallic formation and thermal expansion differences in brazing. By controlling or minimizing the effects of these factors, complicated structures are constantly being fabricated for a large variety of applications.

Transition temperature

The body-centered cubic materials (tungsten, tantalum, molybdenum, columbium, and iron) often exhibit pronounced ductile-to-brittle transition behavior. Below the transition temperature (or temperature range) the metals fracture easily with limited plastic flow. But, the metals can often be readily formed above the transition temperature range. Welds are of particular importance in the ductile-to-brittle transition consideration since large grains, impurity contamination, and, in some cases, recrystallization of parent material all tend to increase the transition temperature.

Typical curves illustrating the effect of temperature on the ductility of various materials are shown in Fig. 1. Sharp drops in the ductility can be seen for tungsten, molybdenum, and iron, while nickel and tantalum show no noticeable transition temperature. Typical transition temperatures in slow bend and tension tests have been reported for recrystallized wrought refractory metals and beryllium and these are listed in Table 1.

Note that beryllium, a hexagonal close-packed metal, also exhibits a transition behavior and two

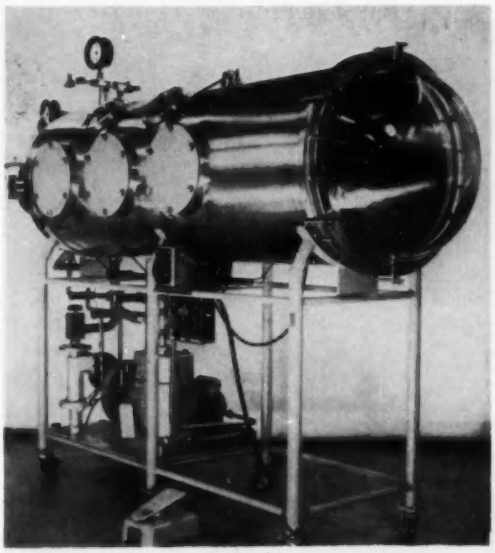


Fig. 2 — Typical controlled atmosphere chamber for welding of refractory metals.

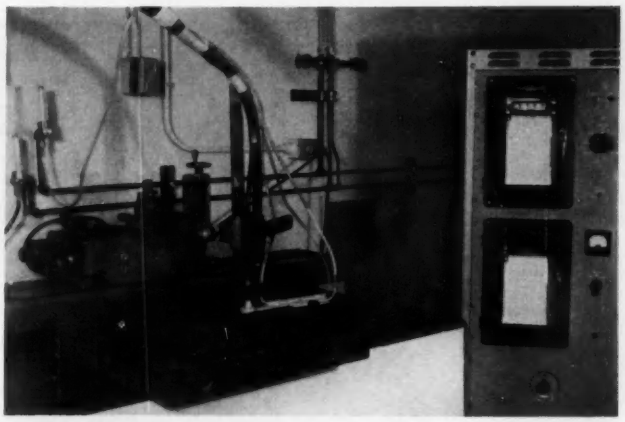


Fig. 3 — Inert-gas consumable electrode welding torch with trailer shield attached.

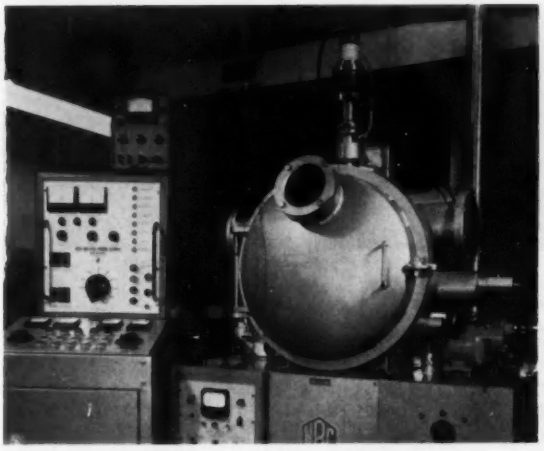


Fig. 4 — Electron-beam welding unit.

Table 1. Transition Temperature for Recrystallized Metals (slow bend or tension test)

Metal	Transition Temperature, C
Tungsten	150–315
Tantalum	< – 195 (if it exists)
Molybdenum	– 30–25
Columbium	– 100 to – 195
Beryllium	0–200, – 50 to – 200

Table 2. Effect of Oxygen on Molybdenum Weld Deposits

	Ductile-to-Brittle Transition Temperature-Bond Test (F)	
(%)	(A)	(B)
0.002	+ 200	– 150
0.005	+ 280	– 75
0.008	+ 310	+ 75
0.01	+ 325	+ 100
0.012	+ 600	+ 100
Unwelded (as-rolled)	– 140	– 250

(A) The lowest temperature at which specimen bent 120 deg.
(B) The highest temperature at which no plastic strain was observed.

separate transition ranges have been reported for this metal.

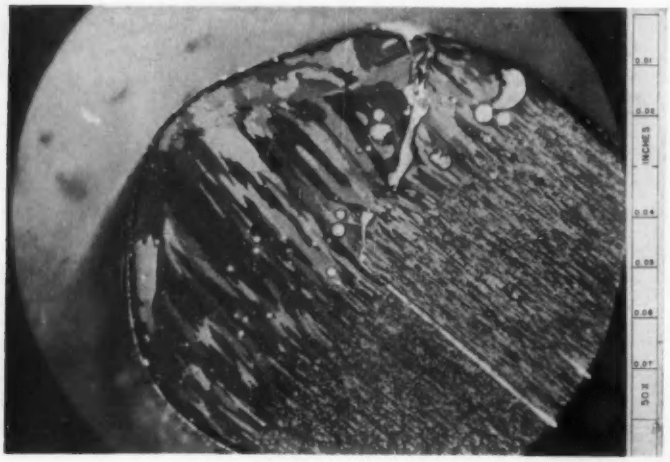
Reactivity with impurities

All of the five metals covered in this discussion react readily with impurities or interstitials such as oxygen and nitrogen with consequent severe reductions in the ductilities of the welds. As a consequence, the welded joints must be protected from the atmosphere both during welding and during cooling.

The influence of impurities upon transition temperature has been strikingly pointed out for molybdenum. The amounts of oxygen picked up by the weld metal and the approximate ductile-to-brittle transition temperatures of the weld deposit are shown in Table 2.

Typical of the special welding techniques required for the refractory metals are those reported for columbium. The most well-known and reliable of the special welding procedures is the use of the controlled-atmosphere chamber (Fig. 2). The chamber can be exacuated, purged and backfilled with an inert gas to ensure exceedingly high-purity atmospheres inside the box.

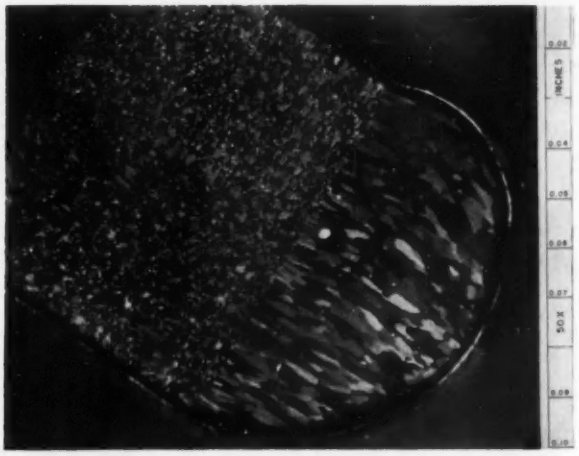
A welding technique which is more commercially feasible utilizes a trailer shield in conjunction with



(a)

Fig. 5 — (a) Beryllium tube-to-end cap weld exhibiting severe porosity. (b) Sound beryllium tube closure weld.

(b)



Joining refractory metals

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the conventional tungsten-arc or inert-gas consumable electrode processes. A shield (Fig. 3) provides additional inert-gas coverage during welding and permits adequate coverage while the weld is cooling. In addition, a pacing shield in front of the torch is sometimes used to provide supplementary protection.

Another method for protecting these metals from contamination is to weld in a vacuum with the electron-beam process (Fig. 4). Such a process approaches ideal conditions of purity, since, at a welding pressure of approximately 10^{-4} mm Hg, the atmospheric purity is better than 99.99999%.

Recrystallization of parent material

Although most materials exhibit their greatest ductility in the annealed condition, the maximum ductility of molybdenum and tungsten is usually obtained in the highly cold-worked condition. Heating them to above their recrystallization temperatures will generally result in brittle behavior at room temperature. This brittleness is attributed to the larger grain size and the rejection of excess phases at the grain boundaries.

During welding, the extent of the recrystallized zones should be kept to a minimum by the suitable selection of welding conditions such as high travel speeds. Recrystallized zones should be avoided, if possible, when brazing by using brazing alloys with flow points lower than the recrystallization temperature of the particular material being brazed.

Porosity

Weld-metal porosity has been reported to be a problem in the joining of molybdenum and beryllium. It has been indicated that the oxide of molybdenum, MoO_3, is sufficiently volatile above 2100 C to cause porosity. Hence, high-purity parent material and high-purity welding atmospheres are essential. Titanium has been reported to be useful as a deoxidizer in the welding of molybdenum, since it forms a nonvolatile oxide which is floated off during welding or remains as spheres and inhibits grain growth.

The presence of severe porosity (Fig. 5a) has been found in end-closure welds in beryllium tubing. It appears that the degree of porosity is dependent upon the material purity and the particular process used for fabricating the tubing, and that the production of porosity-free welds depends upon the careful selection of and control over the various welding variables, such as preheat, welding current, and inert-gas flow rate. A photomicrograph of a sound beryllium tube closure weld is shown in Fig. 5b.

Intermetallic formation and thermal expansion differences in brazing

The applications in which brazing has been used to join the refractory metals have been severely limited by the lack of brazing alloys specifically developed for joining these materials. Although

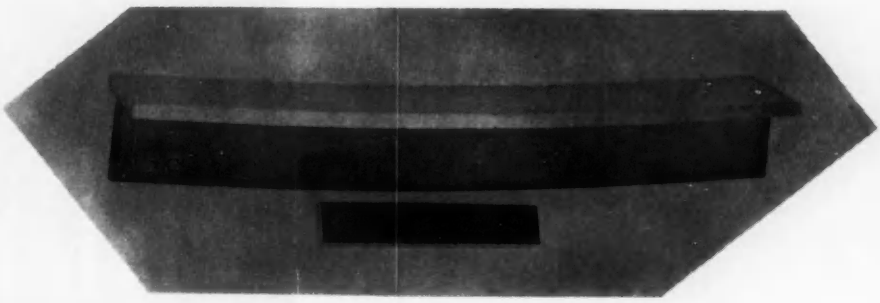


Fig. 6 — Brazed columbium-to-stainless steel T-joint showing severe distortion resulting from the differences in thermal expansion coefficients between the two materials. The columbium strip is the vertical member of the joint.

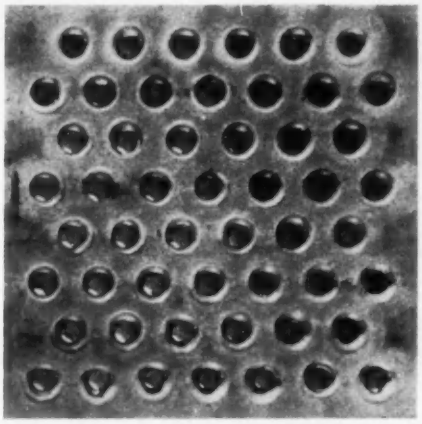


Fig. 7 — Molybdenum heat exchanger.

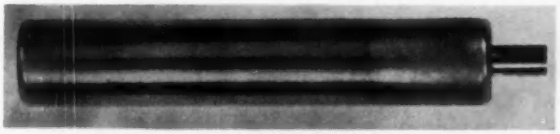


Fig. 8 — Beryllium in-pile tube-burst test assembly.

several references to brazing are present in the literature, the available alloys which are suitable for high-temperature, high corrosion applications are very limited. The use of the conventional high-temperature brazing alloys, such as the nickel-base materials, for brazing refractory metals often results in poor flowability, brittle intermetallic formation, and unfavorable thermal expansion behavior.

Special brazing procedures, such as vacuum brazing are generally required to permit adequate flowability, and the maximum temperature and time at temperature must be closely controlled to prevent the formation of weak, brittle intermetallics. The low thermal expansion coefficients of the refractory metals aggravate the problem if they are to be joined to other metals with higher thermal expansion coefficients, such as stainless steels. As can be seen in Fig. 6, severe distortion and high stresses can be built up in brazed joints between columbium and an austenitic stainless steel upon cooling from the brazing temperature.

Typical applications

Although the problems associated with the joining of refractory metals are numerous and sometimes almost formidable, the fabrication of relatively complex components of these materials has been successfully accomplished. Extremely careful and detailed fabrication procedures have been developed and are considered to be necessary for producing reliable and reproducible welds and brazes in these metals.

Typical of some of the unusual components which have been constructed is the molybdenum heat exchanger assembly shown in Fig. 7. Fusion welding in an inert-atmosphere chamber was found to be a satisfactory method for making the tube-to-header joints, although the resulting welds tended to be brittle.

The nuclear industry provides a variety of unusual and interesting applications for the refractory metals and beryllium. Instrumented in-pile stainless steel fuel assemblies are utilized at the Oak Ridge National Laboratory in which the measurement of extremely high central temperatures is necessary. Tungsten and molybdenum thermocouple wells are routinely brazed to stainless steel in these assemblies, and tungsten-rhenium high-temperature thermocouples with welded junctions are used as the temperature measuring devices.

The fabrication of a quantity of beryllium in-pile tube-burst test capsules was also successfully conducted at Oak Ridge and a typical capsule is shown in Fig. 8. The end closure welds were made by the tungsten-arc process in an inert-atmosphere chamber, and the stainless steel capillary pressuring tube was brazed to the beryllium end cap in helium using induction heating.

To Order Paper No. 340E . . .
from which material for this article was drawn, see p. 6.

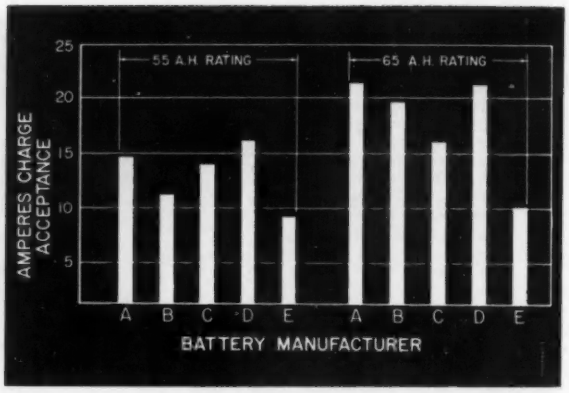


Fig. 1 — A considerable difference exists among two groups of batteries of 55 and 65 amp-hr ratings, as rated through use of the new SAE battery test standard.

New SAE Test Shows HOW

Based on paper by

H. D. Wilson, chairman
SAE Storage Battery Subcommittee

DIFFICULTY in keeping batteries at work in cold weather stimulated inclusion in SAE's newest battery standards of data to determine characteristics of batteries when being charged. Previous standards related chiefly to the battery's performance on discharge.

A test method and minimum-charge acceptance standards have been established by the Storage Battery Subcommittee of the SAE Electrical Equipment Committee. These new standards — which are in the 1961 SAE HANDBOOK — are designed to benefit all those responsible for battery applications. They will help also designers of other electrical system components, because the battery's voltage determines the voltage of the entire electrical system.

New test method

The new test method is based on half-discharged batteries at a temperature of 30 F. Reason: In wintertime, most battery rundowns occur with the battery half-charged or lower. For comparison purposes, a 14.4 v charge voltage at battery terminals was arbitrarily selected.

As outlined in Table 1, the method requires that a new and untested battery be brought to a temperature of 70 to 90 F, then that it be fully charged at a rate equal to the 20-hr rate of discharge. Next, it is discharged at a rate of 15 amp (if a 12-v battery); at 30 amp (if 6-v) for 50% of its rated amp-hr capacity. Then it is cooled to 30 F and charged at 14.4 v (if a 12-v battery) and at 7.2 v (if 6-v) for 10 min. The current flowing through the battery at the end of 10 min is taken as a "Charge Acceptance Rate."

Checked by this method, batteries of present-day manufacturers differ widely as to charge rate acceptance, as noted in Fig. 1. A considerable difference is shown to exist among individual units in these two groups of batteries of 55 and 65 amp-hr ratings. Each group consists of batteries as produced by five representative battery manufacturers.

In the group of 55 amp batteries, the charge acceptance rates vary from 9 to 16 amp; in the 65 amp-hr group, from 10 to 21 amp.

Fig. 1 also shows that, in general batteries of higher amp-hr capacity rating, when half-discharged, accept considerably higher rates of charge for the same impressed voltage than do the batteries of lower amp-hr rating.

Fig. 2 gives results of a similar comparison using similar groups of 55 and 65 amp-hr batteries made by the same manufacturers, but by a dry-charge process. The results are shown alongside the rates for equivalent wet-processed batteries.

Reasons for variations

There are many reasons for the variations indicated. The electrochemistry of the charging process can be a factor of importance. Involved also are such things as state of charge; rate of charge; area of plates per cell; resistance of separators; antimony content of positive plate grids; specific gravity of electrolyte; process of plate curing ... presence of organic expander in negative plates; presence of metallic ions other than lead; and age of battery.

Then too, unless the temperature of the regulator

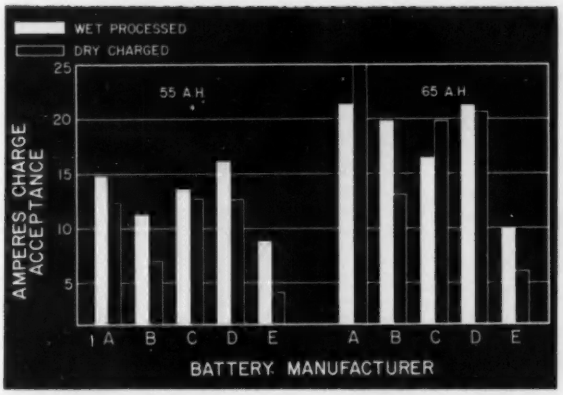


Fig. 2 — Results of comparison similar to that made in Fig. 1 using similar groups of 55 and 65 amp-hr batteries made by the same manufacturers, but by a dry-charge process.

Table 1 — Procedure for Determining Charge Rate Acceptance

1. Bring new, untested battery to 70–90 F acid temperature.
2. Fully charge at rate equal to 20-hr discharge rate.
3. Discharge 12-v battery at 15 amp, or 6-v battery at 30 amp, for 50% of its amp-hr rating.
4. Cool to 30 F.
5. With battery in 30 F ambient, charge 12-v battery at 14.4 v, or 6-v battery at 7.2 v, for 10 min.
6. Charge rate at 10 min is taken as charge acceptance rate.

and WHY Batteries Vary Greatly

and battery are properly coordinated temperature-wise, the on-charge voltage of a hot battery is so low that the system's voltage — as determined by the voltage-limiter setting of the generator regulator — will force excessive charging current through the battery.

In such a case, a severely overcharged and overheated battery can result . . . which leads to excessive water loss from the cells. By decomposition of water into hydrogen and oxygen gases.

Loss of water from overcharging produces a high concentration of the remaining acid and a drop in liquid level which will, if not detected and the water replenished, be very detrimental to the plates and separators.

Excessive water consumption by a battery is a valuable indication to warn that a voltage regulator setting may be too high for the conditions of operation of the vehicle, or it may indicate a battery subjected to excessive heat. It may also indicate existence of a defective battery cell.

Cars driven great mileages at high average speeds in hot climates may require a lower than normal voltage regulator setting to prevent overcharge and battery damage.

The most satisfactory voltage regulator setting is that which maintains the battery in a satisfactory operating state of charge with a minimum amount of water consumed. Under such conditions it should not be necessary to add water to battery cells more often than once every two thousand miles to keep the electrolyte level above the separators. 100 amp-hr of excess charging current will account for 1.18 oz of water decomposition per cell to which would be added that lost by evaporation.

Batteries should not be asked to operate the prolonged periods of time with acid electrolyte temperature much above 125 F if longest life is desired. Excessive heat sustained over a long period of time can be very detrimental to the cell components.

Use of alternator-rectifier charging systems having performance characteristics superior to conventional d-c generators will have an important effect on maintenance of battery charge. When proper alternator-to-engine drive ratios are used, the alternator can develop a higher voltage and current at lower engine speeds. So, it will be capable of supplying a greater portion of the electrical load requirements of the vehicle under low speed driving conditions. The battery, therefore, should be obliged to carry much less of the load at low engine speed, and should remain in a higher state of charge during winter weather. However, a realignment of the voltage regulator's temperature compensation may be required and lower voltage regulator settings may be used with the alternator to prevent overcharging the battery in hot weather. The overall result should be fewer discharged batteries in winter operation.

Generally speaking, a larger battery will have greater reserve capacity and should have longer service life.

In spite of its changeable characteristics, the low-cost lead-acid battery has delivered splendid performance under the most adverse climatic conditions, and often in the face of deplorable neglect.

Battery engineers and manufacturers still have much work to do to improve battery uniformity and to extend battery life. Likewise, the engineers concerned with the installation and maintenance of batteries must be fully aware of the battery's limitations if longest life and extended trouble-free battery service are to be realized.

Material in this article is drawn from one of 12 papers included in SAE Technical Progress Series, Volume 3: Storage Battery Symposium — 1961. To order this publication, TPS-3, see p. 6.

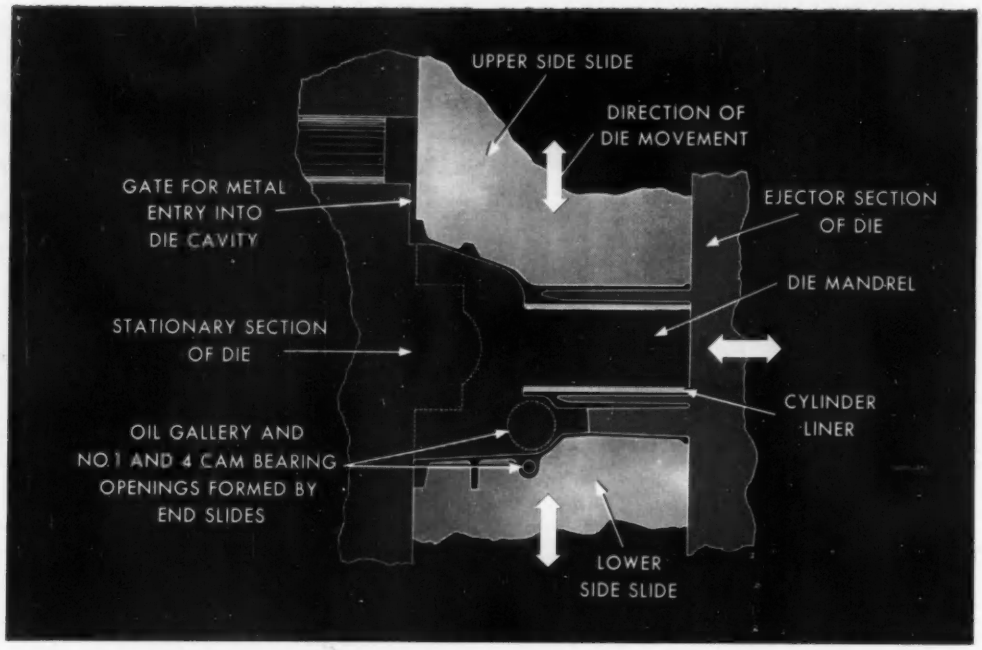

UPPER SIDE SLIDE
DIRECTION OF DIE MOVEMENT
GATE FOR METAL ENTRY INTO DIE CAVITY
EJECTOR SECTION OF DIE
DIE MANDREL
STATIONARY SECTION OF DIE
CYLINDER LINER
OIL GALLERY AND NO.1 AND 4 CAM BEARING OPENINGS FORMED BY END SLIDES
LOWER SIDE SLIDE

Fig. 1 — **SECTION OF CYLINDER BLOCK DIE** for die-casting Chrysler Corp.'s aluminum slant six engine.

Die-casting the aluminum slant six engine

Aluminum block saves 76 lb on 225 cu in. engine for 1961 Plymouth, Dodge Dart, and Dodge Lancer

Based on paper by

E. G. Moeller, W. L. Weertman, and H. E. Eriksen

Chrysler Corp.

CHRYSLER CORP. chose to die cast its aluminum block for the slant six engine because it provided the best possibilities for lowest weight, lowest overall cost, and most consistent production quality.

The lowest weight is possible because wall sections can be tailored to meet the strength requirements based on a fatigue strength of 10,000 psi. Where wall sections do not carry appreciable loads, thinner sections can be cast by the die-cast process than by other means. (However, the engine design must be carefully planned so that with a reasonable number of slides in the die, the desired shape can be produced with a minimum amount of unnecessary and low stressed metal.)

The lowest overall cost of an aluminum block is the result of a combined lower cost of tooling, casting, and machining.

Production quality is generally considered to be superior and also more consistent in die castings because the process is less likely to be affected by human factors.

Following is a description of the die-cast process.

Die design

The casting die is designed with the cylinder axis in the horizontal plane (Fig. 1). The crankcase core and mandrels which support the cylinder sleeves during casting are mounted in the stationary part of the die. The four sides of the block plus the cored out top surface are formed by die pieces mounted in the movable or ejector half of the die. To allow the ejector half of the die to function, the portions of the die forming the four sides are mounted on slides to provide means for retraction.

To core the holes, which are at angles to the direction of the slide movements and die opening, hydraulic cylinders are used. Hydraulic cylinders

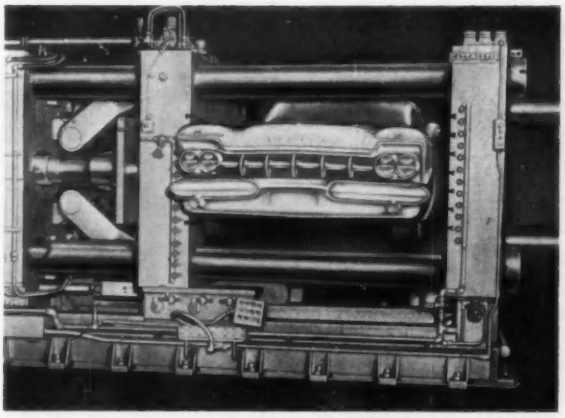


Fig. 2 — Imperial mounted in **ALUMINUM CYLINDER BLOCK DIE-CASTING MACHINE** gives indication of machine size and rigidity of supporting structure.

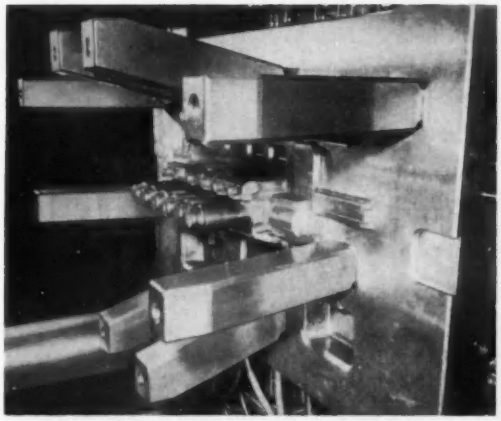


Fig. 3 — **STATIONARY HALF OF DIE** assembled on die-casting machine.

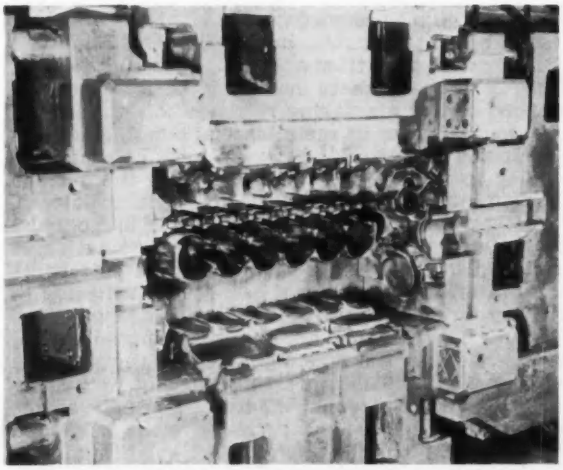


Fig. 4 — **EJECTOR HALF OF DIE** with side slides assembled on die-casting machine.

The slant six engine . . .

. . . has six cylinders in line, with a 3.40 in. diameter cylinder bore and a 4.12 in. piston stroke.

It has a compression ratio of 8.2/1. Engine displacement is 225 cu in.

The engine is tilted 30 deg for most efficient use of engine compartment space.

It features overhead in-line valves in an open, wedge-shaped combustion chamber.

Mechanical tappets and fabricated stamped steel rocker arms are used in the push rod-operated valve mechanism.

Cylinder liners, cylinder head, and intake manifold are made of cast iron.

are also required to core the oil gallery holes because of the 13-in. core pull. The die assembly weighs about 44,000 lb and is 83 in. wide, 60 in. high, and 49 in. thick.

Die-casting machine

A 2000-ton die-casting machine provides the locking force to withstand a metal pressure of 8000 psi. To maintain these pressures in the die, fill the complete cavity, and achieve a rapid machine cycle, eleven accumulator bottles and 5-in. hydraulic lines are used. The size of the machine and the rigidity of the supporting structure is indicated in Fig. 2. The die assembly is shown mounted on the machine in Figs. 3 and 4.

Casting development

Since the engine cylinder block is a highly stressed part, there is need for good metal quality, particularly as regards to porosity and "cold shuts" which are common problems in aluminum castings. This required development of the proper metal casting temperature, die temperature control, metal overflow points, gating, and other techniques of the art. In addition, the development program must also take into account requirements for dimensional control which are affected by the die operating temperature, as well as dimensional variables. One of the most difficult dimensional tolerances to maintain is that of keeping cylinder bore centers within 0.015 in. of their specified locations.

To provide good castability of the cylinder block, it was decided to use SAE No. 303 die-casting alloy containing 3–4.5% copper and 10.5–12% silicon.

To Order Paper No. 307C . . .
from which material for this article was drawn, see p. 6.

Cooled structure aids

Based on paper by

Herbert Mund

Bell Aerosystems Co.

THERMAL protection of a manned boost-glide, earth orbiting, vehicle may be accomplished by providing a cooled and insulated load-bearing structure. This type of construction utilizes a double-wall. A conventional, riveted aluminum inner wall, through which a suitable coolant is circulated, is separated by insulation from an outer wall composed of high-temperature shields. The construction of the double-wall is shown in Fig. 1.

Aerodynamic friction heat is transferred, by forced convection, through the boundary layer to the shields. Approximately 95% is radiated back into space, thereby sustaining the shields at temperatures between 1000 and 2600 F. The remaining 5% is transferred through the insulation to the primary aluminum structure (the inner wall). It is the purpose of the cooling system to absorb this heat so that the inner wall may be maintained at approximately 2000 F.

The cooling system requires least power when the heat is transferred to an expendable mass. If it were attempted to transfer the heat back to the external shields, the temperature of rejection would have to be above 1000 F. This could, theoretically, be done by means of intermediary vapor or gas compression cycles, but large amounts of power would be required to operate the machinery. In the expandable system the heat is absorbed by aqueous glycol which is circulated through the inner wall structure. The heat is then carried off to a central heat exchanger, where it is rejected to an expendable liquid such as water, which is boiled. A schematic of the structural cooling system appears in Fig. 2.

The open side of the cooling system is comprised of a stowage tank for the expendable fluid, and a suitable flow control valve. The water metering control valve is actuated by vapor pressure from an ethyl ether bulb immersed in the hot side of the aqueous glycol loop. The low pressure steam, saturated or superheated, is exhausted overboard at approximately sonic velocity.

The cooled inner wall of the vehicle is made up of panels approximately 6–8 ft in length and 2 ft wide, as shown in Fig. 3. Cooling passages extend lengthwise along the panel in a simple parallel arrangement. The passage dimensions are approximately 7/16 in. wide by 47 mils in height, and they are spaced about three inches apart. Common headers at each end of the panel join the coolant passages. Only four external connections are required for each panel regardless of the number of coolant passages. The panels are connected to one another by flexible hose assemblies, which connect the ends of the adjoining header passages. An integrated network of panels is formed in this manner, to properly distribute coolant throughout the insulated surface of the primary structure.

Panel fabrication

Unlike many familiar tube-on-sheet heat transfer applications, the fabrication of coolant passages on the primary aluminum structure for, cooling of a hypersonic aircraft requires:

1. The distribution of coolant over relatively large surface areas complicated by splice joints, doors, and canopys.
2. Mechanical integrity under high elastic strains and deflections resulting from inertia and aerodynamic forces.
3 Mechanical integrity during exposure to mechanical vibrations resulting from rocket engine and boundary layer noise.

At the outset adhesives were considered for use in attaching tubes to structural sheet material. After testing, the inadequacies of adhesive bonding became quite evident, so welding was tried. In this application, the upper surface of a coolant passage was formed by stamping, from sheet material, a cover having a hat-like cross-section. By welding this along each side to the skin of the structure the coolant passage is formed. Unfortunately, this configuration, with two feet of weld for every foot of passage, proved highly susceptible to leakage. Mechanical failure was also high for this design.

Two other techniques, brazing and metallurgical bonding were then tried and turned out successfully. Brazing tube-on-sheet has long been a popular method of manufacturing refrigeration appliances, but the technique of metallurgical bonding is more recent and rather interesting. In some respects it is similar to the bonding of alclad onto the surface of aluminum sheets. Essentially, a tube pattern, including the headers, is printed with colloidal graphite on the face of one sheet. A second sheet is staked to this sheet with the printed pattern at their interface. The two sheets are then heated to an appropriae temperature and hot rolled together. It is this hot roll which accomplishes a metallurgical bond, except in the region covered by the graphite parting agent. Tubes are subsequently formed by inserting an entry tool at the interface of the sheets and applying hydrostatic pressure to the unbonded region. Fig. 4 shows a photomicrograph of a metallurgically bonded section.

The metallurgical bonded sheets are made of alclad 2024 aluminum alloy, and the brazing tech-

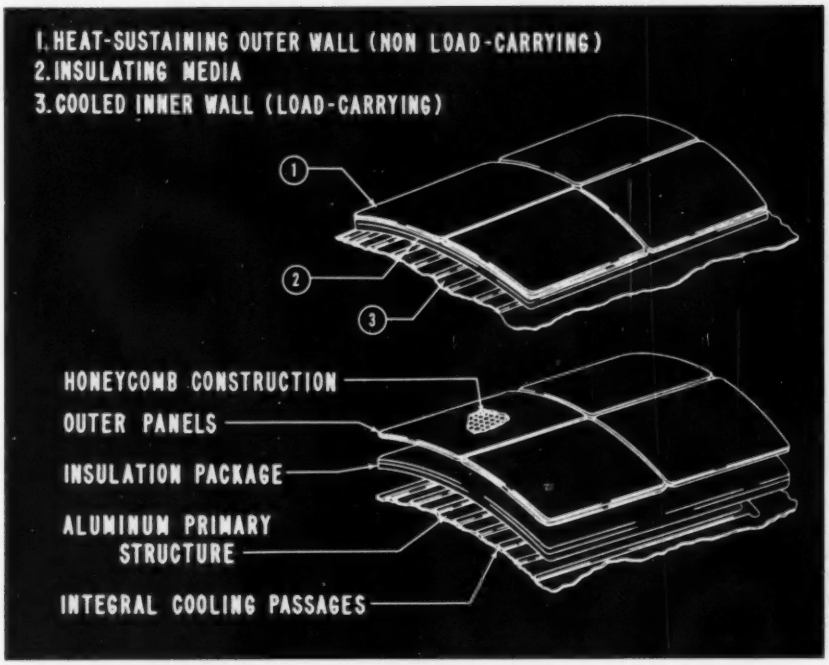
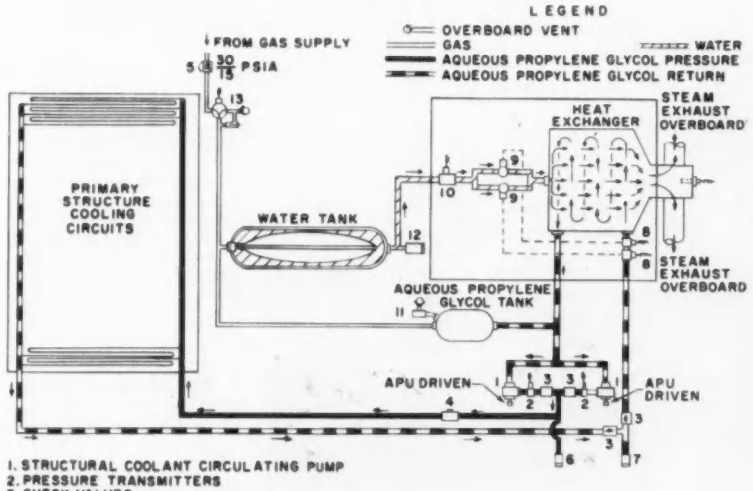


Fig. 1 — Double-wall consists of non-load-carrying, independently supported, high-temperature shields which connect to the inner wall. The inner wall of aluminum is the primary structure and has integral cooling passages. Insulation in foil containers separates the two walls.

hypersonic flight

Hypersonic flight in the upper reaches of our atmosphere presents unprecedented thermal environment conditions. Induced temperatures as high as 2000 F for sustained periods of 1-2 hr demand some system for energy dissipation. One answer to the problem is revealed in this article.



1. STRUCTURAL COOLANT CIRCULATING PUMP
2. PRESSURE TRANSMITTERS
3. CHECK VALVES
4. RESTRICTORS (ADJUSTABLE)
5. REGULATOR
6. G.S.E. COOLING UNIT PRESSURE CONNECTION
7. G.S.E. COOLING UNIT RETURN CONNECTION AND FILL VALVE
8. TEMPERATURE SENSORS
9. FLOW MODULATING VALVES
10. FLOW METER
11. MANUAL VENT VALVE
12. FILL AND DRAIN VALVE
13. THREE-WAY SOLENOID VALVE BUILT-IN RELIEF

Fig. 2 — Circulating through the primary structure is the aqueous glycol coolant. The coolant transfers its heat to the expendable mass, water in this case, in the heat exchanger. The steam that is formed in the exchanger exhausts overboard.

Cooled structure aids hypersonic flight

. . . continued

nique utilizes both 6951 and 6061 aluminum alloys.

Structural testing of panels utilizing these two types of cooling arrangements showed their feasibility. Permanent change of shape of the coolant passage were found to be of tolerable magnitude for the metallurgically bonded structure and insignificant for the brazed panel. The mechanical integrity of both types of coolant passages was also tested in the presence of severe vibration. Application of 130 decibels for 30 min; an energy level comparable to the aerodynamic acoustic environment typical of this type aircraft, caused no physical damage. One-hundred and fifty decibels operating over longer duration did produce a fine crack in the bonded structure, but the brazed section remained unscathed. Both types were also found to have adequate factors of safety for hydrostatic pressurization. The method selected was the metallurgical bonding technique.

System thermal design

The mechanical properties of many solution heat-treated aluminum alloys are essentially retained up to a temperature of 250 F. Consequently, the outlet temperature of the coolant must equal 250 F less the gradients incurred in the skin between the coolant tubes and across the fluid film at the tube walls. For a tube spacing of 2 9/16 in., a coolant outlet temperature of 155 F was found to be slightly conservative. The fluid is cooled to 95 F in the heat exchanger.

The selection of suitable water boiling conditions is next considered. A lower limit is placed on the evaporation pressure by the specific volume of saturated vapor and heat transfer effectiveness. Studies of a compact heat exchanger suggested a minimum boiling temperature of approximately 80 F and a log mean temperature difference of 45 F. The saturated vapor pressure of the evaporated water was approximately 0.5 psia.

With the above tube spacing and a heat flux of 2300 Btu hr-ft^2, the required circuit flow is computed. In this case the specific heat of the coolant is 0.83 and the temperature rise is 60 F. The required flow is computed to be 92.5 lb/hr. Since the fluid is heated in the header passages, to some extent, the available temperature rise is diminished in the direction of a system extremities. The net effect is that the required flow increases in each successive circuit. Flow must then be controlled in each individual circuit. This may be effected by incorporating a length of reduced tube cross-section within each coolant circuit, as shown in Fig. 3.

To Order Paper No. 280C . . .
from which material for this article was drawn, see p. 6.

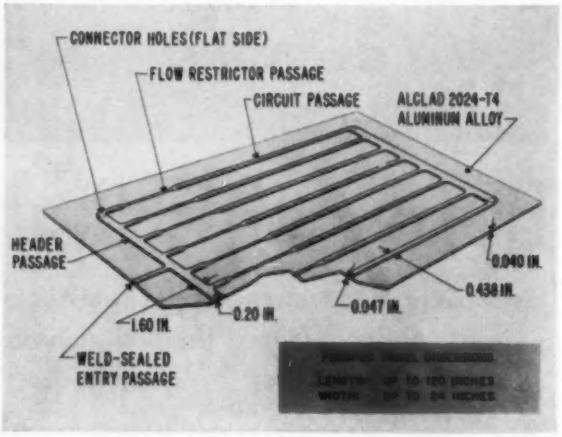


Fig. 3 — Structural panels contain integral cooling passages, with flow restrictions, and two headers. The individual panels are interconnected by flexible hose assemblies to form an integrated network of panels.

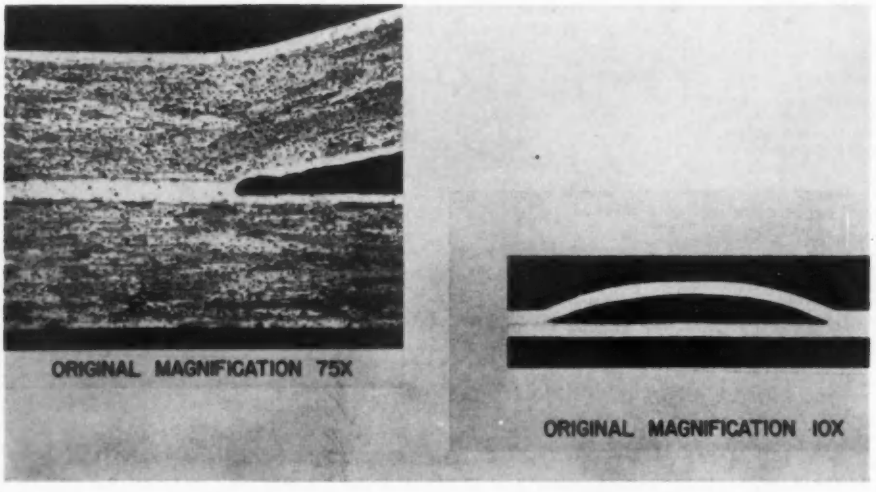


Fig. 4 — Metallurgically bonded sheets with integral coolant passages are shown in magnified cross-section. Bonding is achieved by hot rolling. The tubes are formed by printing the required pattern on one sheet, at the interface. This parting agent does not allow bonding to occur along the printed pattern. Applying hydrostatic pressure to the unbonded regions forms the passages.

Automotive Engineers are solving an increasing variety of problems by

turning to computers

Applications are advancing from solutions of simple, one-thing-at-a-time problems to analyses of complex systems involving integration of many components. Some of these more advanced applications are discussed here.

Based on talk by

R. K. Louden

International Business Machines Corp.

FUNCTIONS of automotive engineering and administration that are now being assisted by — or considered for assistance by — computers include:

- Product design.
- Prototype construction.
- Design of experiments.
- Performance forecasting.
- Management controls.
- Solving problems involving dynamic systems.
- Reading engineering drawings.

Product design — from components to systems

A few years ago the standard method used in the design of automotive gears was the layout technique in which the individual gear teeth were laid out on a drafting board to check them for interference, etc. Then desk calculators were used to compute parameters such as pressure angle, which might affect the desirability of a given design. When digital computers were first applied to this task, they calculated much the same sort of information which had previously been produced by hand, only they calculated much more of it. The computers used a shotgun approach, which calculated many gear configurations, one after the other, to give the engineer a choice of many designs.

The next step was component optimization. The computer could, if given the standards by which the engineer chose his "best" design, automate the choosing process. In this way, the computer could optimize the design of a gear according to predetermined criteria of performance.

Now a whole set of mating gears can be design-optimized inside a computer, by having the computer consider first one gear and then another, employing iteration to move toward an overall optimum for the whole gear system, which may involve compromises in the optimization of the individual gears. Now many components with interacting performance characteristics can be designed and optimized as a single system, involving quantities of calculation worthy of the powerful computers available today.

During the last few years, computers have been used in the design of steering linkages, beams, drivelines, braking actuators, coil springs, air springs, suspension linkages, engine balancers, torque converters, and many other components and subsystems. The next step in computer-based design technique will probably be the combining of these subsystems into larger systems to permit better opitmization of the total system, the automotive vehicle.

In an interesting paper on suspension geometry,[1] Ford engineers discuss the automation of suspension layout, resulting in the precise calculation of camber, caster antidive forces, steering arm ball joint travel, and spring characteristics over the com-

[1] "Computer Solves Complex Suspension Geometry Problems," by K. L. Hoyt, C. F. Maddox, N. R. Miller, and D. F. Zawada, *SAE Journal*, August 1960, pp. 71–75. Based on Paper No. 127A, presented at SAE Annual Meeting, January 1960.

plete range of wheel travel. In the future such suspension programs may be expected to grow in generality and scope to enable further reductions in the design time required for new suspensions. As the authors pointed out in their paper, conventional layout techniques are frequently insufficient for the analysis of low frequency suspensions. Future designs may well include a wide range of suspension configurations, since the designer is no longer limited by what he can analyze graphically. Eventually, suspension programs may end up as subroutines in chassis design master programs, which would be capable of analyzing the automotive chassis as a single large system.

The design of engine mounts has been considered as a system by Earle Stepp of Chrysler.[2] As the multiple engine mount schemes employed in modern passenger cars constitute a complex dynamic system with many degrees of freedom, he found that it was almost impossible to predict the performance of engine mount changes from experimental data alone. However, by using a digital computer and matrix analysis he was able to consider the whole system at once and produce design solutions which (to quote his paper) "played a very significant role in improving the quality and performance of the manufactured product."

A current project at Ford involves the design analysis of large automotive body structures, necessitating the solution of as many as 200 simultaneous equations. To meet this challenge Ford engineers and mathematicians are developing a special problem-oriented language to accept geometric statements concerning the structure and to develop coefficients for the resulting matrix.

Prototype construction — numerical control is knocking at the door

Frank Walker at Buick has been concerned with the development of torque converter blade shapes for several years, and during much of this period he has been assisted by various computer programs. In 1960, however, he passed a milestone in quick prototype construction by turning out torque converter cores on a tape-controlled milling machine.[3] By using one computer program to calculate and produce a graph of torque converter blade profiles from hydraulic requirements, followed by another computer program to calculate instructions for the milling machine from the profiles, he was able to cut lead time in half while realizing a substantial improvement in dimensional accuracy.

Gorham and Ballinger of Bendix Industrial Controls commented favorably[4] on the feasibility of using numerically controlled machine tools to produce prototype body parts to meet new competitive requirements for complex shapes, high accuracies, and minimum lead times. While this may still be around the corner for automotive manufactures, Boeing in Wichita has been providing a numerical control consulting service[5] and producing dies for many companies not too unlike those used to stamp out automotive body sheet metal. Numerical control looks like a sure bet for automotive expansion in the 1960's.

Design of experiments — not as easy as it looks

The design of statistically adequate experiments to test the performance of new prototypes is compartively virgin territory, where relatively simple computer programs involving a small number of statistical principles can effectively ride herd on thousands of variables in hundreds of experiments to ensure that the engineer's results will have a maximum probability of meaning what he thinks they mean.

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[2] "Computer Designed Engine Mounts Control Car Shake," by E. Stepp, *SAE Journal*, May 1960, pp. 29–33. Based on Paper No. 127B, presented at SAE Annual Meeting, January 1960.

[3] "Computer Takes over, for Product Design and Manufacturing," by R. Heslen, *Tool and Manufacturing Engineer*, November 1960, pp. 86–87.

[4] "Numerical Control in Body Engineering — Fact and Fantasy," by J. C. Gorham and J. R. Ballinger. Paper No. 129A, presented at SAE Annual Meeting, January 1960.

[5] "Control Media Preparation Facilities," a report of Boeing Airplane Co., Wichita, Kan.

[6] "Data Systems in AASHO Road Test," by P. Irick. Paper No. 116B, presented at SAE Annual Meeting, January 1960.

[7] "New Concept Aids Vehicle Handling," by W. Bergman, *SAE Journal*, September 1960, p. 85. Based on Paper No. 186A, presented at SAE Summer Meeting, June 1960.

[8] "Computers Analyze Drivetrain Design," by S. E. Staffeld, *SAE Journal*, June 1960, pp. 38–40. Based on Paper No. 127C, presented at SAE Annual Meeting, January 1960.

[9] "At Ford . . . Computer Predicts Car Acceleration," by H. L. Setz, *SAE Journal*, October 1960, pp. 68–75. Based on Paper No. 196B, presented at SAE Summer Meeting, June 1960.

[10] "Computers Simulate Acceleration and Fuel Economy of Passenger Cars," by R. K. Louden and I. Lukey, *SAE Journal*, September 1960, pp. 52–55. Based on Paper No. 196A, presented at SAE Summer Meeting, June 1960.

[11] "New Simulator Is Aid to Better Ride Analysis," by R. H. Kohr, *SAE Journal*, April 1960, pp. 149, 151. Based on Paper No. 144A, presented at SAE Passenger-Car Meeting, March 1960.

[12] "Optimum Performance of Random Access Data System," G. L. Licht. Report No. GMR-307, published by General Motors Research Laboratories, Warren, Mich.

[13] "Now, a Do-It-Yourself Computer for Engineers," by J. T. Olsztyn, B. Hargreaves, T. J. Theodoroff, and E. L. Jacks, *SAE Journal*, April 1960, pp. 32–34. Based on Paper No. 127D, presented at SAE Annual Meeting, January 1960.

An example of the decisions encountered in multivariable experimentation is provided by Paul Irick in his discussion of road material testing.[6]

Performance forecasting — simulation by computers

The simulation of real situations by digital computers has rapidly progressed from simple systems to complete automotive vehicles. It promises to grow into operational system simulations considerably more involved than the physical system simulations which now see routine use at General Motors, Ford, and Chrysler.

Water Bergman of Ford has simulated the forces acting on a cornering tire under traction by considering the tire as a three-dimensional spring.[7] S. E. Staffeld of Chrysler has simulated the vibrations of an automotive drivetrain.[8] Henry Setz of Ford has simulated the acceleration of an entire automotive vehicle,[9] and Buick engineers have simulated the fuel economy of automotive vehicles running over real test routes.[10]

Complete vehicle simulations involve the step-by-step calculation of all significant parameters affecting engine, transmission, and chassis performance and are generally beyond the capacity of hand calculation. An important byproduct of vehicle simulation in the future may be reliability projections. Since the simulation reveals the time spent at each combination of torque and rpm while traversing the test route, it should be possible to use these data to forecast the life of the components exposed to this test route. Thus, the effect of engineering changes upon both reliability and performance could be simulated.

Robert Kohr of General Motors Research has made significant inroads on the problem of ride simulation.[11] Automotive riding characteristics are one of the last big engineering areas to be handled quantitatively on large-scale computing equipment. Kohr's method of attack includes the use of a ride simulation machine which enables a human observer to experience the motion resulting from a given road contour and suspension configuration. We may see other systems in the future in which it is necessary to insert a man into the analysis to make judgments which cannot be set up as quantitative rules.

A rather different sort of simulation has been described by G. L. Licht of General Motors Research.[12] He has simulated the operation of a random access data processing system on a digital computer in an effort to optimize the addressing scheme used by the random access system. In the future, we may expect to see many operational systems such as inventory control and production scheduling become routine simulation projects.

At least one automotive manufacturer is simulating final assembly tolerance specifications from component tolerance limits in an effort to optimize component tolerances. Monte Carlo techniques are used to generate randomly sized components.

Management controls — operations research

The Ford Tractor and Implement Division in Birmingham is using an inventory control program based on exponential smoothing techniques to produce forecasts, vendor releases, economic order quantities, and orders. This computer application is becoming typical of many such management operating systems throughout the industry. General Motors Research has successfully simulated warehouse operation on a computer to compare the effect of different order policies, and we may expect to see the large-scale simulation of many types of management problems in the future.

PERT, which is a computer-based system for keeping track of complex precedents in a chain of events, is also the probable forerunner of a family of new management tools.

Solving problems involving dynamic systems — problem-oriented languages

Although FORTRAN and similar algebraic languages now make computer programming a straightforward business once a problem has been reduced to the level of algebra, there is still a real problem for those engineers working with complex systems which are not ordinarily described algebraicly. General Motors Research has solved this problem for one class of engineering applications with their DYANA programming system.[13]

DYANA accepts descriptions of spring-mass systems (and other analogous systems) and then proceeds to set up differential equations to describe the system. DYANA then develops an algebraic scheme to solve the differential equations, and prints this out as a FORTRAN program ready to re-enter the computer to get final answers. The user of DYANA in general does not need to know either the physics or the mathematics necessary to solve his problem; this feature made DYANA a real breakthrough of the 1950's. If the DYANA concept can be applied to other engineering areas, an enormous reduction in engineering programming effort may be realized.

A simpler type of problem-oriented language is used at Buick, where a file of prototype engines, transmissions, and chassis is kept on magnetic tape. These components can be assembled by the computer to form a mathematical model of an entire vehicle for simulation applications. A few English language commands are all that is required to "build and test" almost any combination of components in the file.

Reading engineering drawings — pattern recognition — a next big step?

Current work on pattern recognition and optical scanners makes us wonder if we may not eventually see a computer capable of reading engineering drawings. A device such as the MIT light pen could be used to draw sketches for the computer to read, and if the computer could store and retrieve such drawings, another enormous field of application would be opened.

Curve readers are now in use at Ford and GM to read graphical data directly into computer language.

To Order Paper No. 271A . . .
from which material for this article was drawn, see p. 6.

Testing rockets inexpensively

Based on paper by

G. R. Rewerts and P. J. Swanson

Convair Astronautics, Division of General Dynamics Corp.

A RELATIVELY inexpensive method has been developed for controlling and programming both heat flux and structural loads, for testing aircraft and missiles. It consists of an open loop system which applies stepped d-c voltages to d-c motors which control heat flux and structural loading, by driving potentiometers and varying pressure regulator settings respectively. The potentiometers control the power to banks of heating elements and the pressure regulators control hydraulic pressures to the load cylinders. The relative saving that this system affords is indicated in the cost of the temperature and the heat flux programmers. These items alone cost about $29,350 (approximate 1957 figure) less than similar apparatus used with a closed loop system. This saving is almost equal to the entire cost of the open loop heating system.

This method of testing is very useful in designing missiles, as it simulates aerodynamic heating of the missile skin. This type of heating was recognized early in the Atlas ICBM design to be of sufficient magnitude as to affect structural integrity. In addition, radiant heating of the thrust barrel by the vernier control rocket motors is also present. The areas established as critical were the nose cone adapter and the thrust barrel. Both of these structures are of ribbed skin construction. Temperature differentials across the ribs could create stresses and deflections of considerable size. By conducting full scale tests simulating heat and load, many design questions are answered.

Test requirements

A typical test program might be similar to that carried out for the Atlas ICBM. Here various flight conditions are simulated for the nose cone adapter by applying heat and loads. The resulting stresses and deflections are then measured. In addition an ultimate test program is performed in which loads and temperature are simulated as a function of time. Thrust barrel tests involve temperatures which vary not only with time, but also with location on the barrel.

Heating is supplied by elements radiating at a maximum rate of 10,000 Btu/sq ft/hr over the 450 sq ft of specimen area. Power to the elements is 1500 kva at 440 v, varied by a controller and divided into six individual channels. Three variable pressure regulators are used to program 3000 psi hydraulic pressure to the loading cylinders.

For varying the heating and loading rates as a function of time, up to the maximum test duration of six minutes, a six-channel programmer is used.

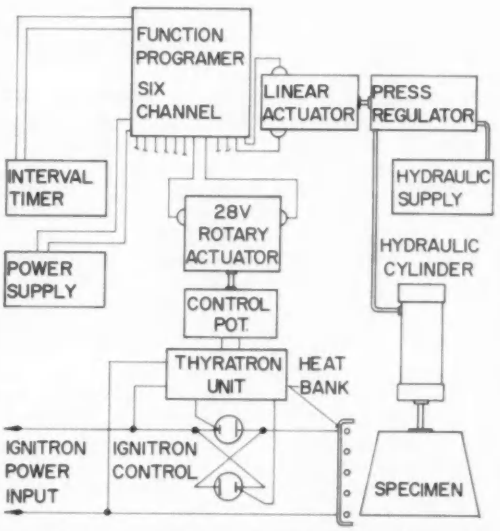


Fig. 1 — Schematic of the aerodynamic heat and load controller. The six channel function programmer supplies signals to the two actuators to vary the structural loading and the heating. The ten steps provided in each channel, along with the interval timer, allows the heat and load to conform to given requirements.

Equipment

The heat controller consists of six pairs of size D ignitron power tubes connected in an inverse-parallel circuit, each pair being fired by a thyratron control circuit. The thyratron circuit contains the heat control potentiometer which is positioned mechanically by a 28 v d-c rotary actuator. This actuator is supplied with stepped signal voltages for excitation, from the programmer. Reversing the actuator, by switching polarity of the signal voltage, decreases the available power. This arrangement, shown schematically in Fig. 1, provides six individual heat control channels. If desired, all six heat control potentiometers can be ganged together so that all ignitron circuits could be programmed as a single unit.

The hydraulic pressure to the load cylinders is controlled by varying the pressure regulator setting with a 28 v d-c linear actuator. The rate of change of pressure is proportional to the signal voltage. The magnitude of the applied load is a function of the size of the loading cylinder.

The programmer consists of a six-channel, step type function generator. Each channel has ten step positions, each step being in effect, an independent

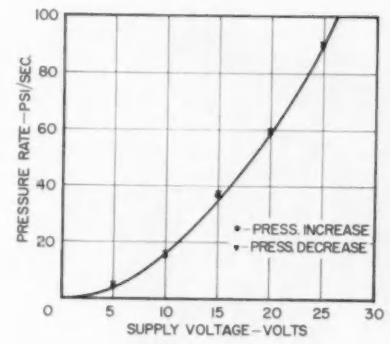


Fig. 2 — Typical calibration curve for load system control. The pressure regulators functioned equally well with increasing and decreasing pressures.

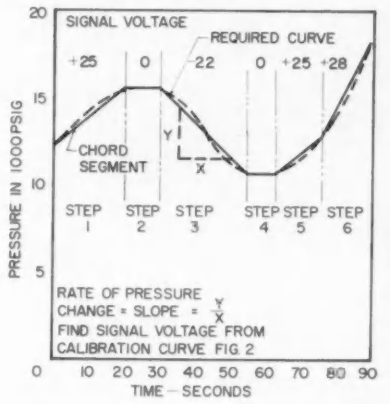


Fig. 3 — Using the data of Fig. 2 the required load curve (converted to pressure) is approximated by chords of varying length. The slope of the chord required for a given interval gives a required pressure rate. The signal voltage to give this rate is found in Fig. 2.

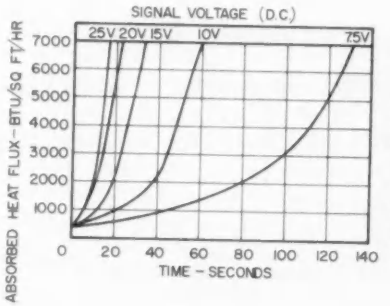


Fig. 4 — The change in flux with time, for given signal voltages, is shown in these calibration curves. If the required heat curve is approximated by chords, the slopes of the various chords may be matched by choosing a signal voltage that yields an equal slope.

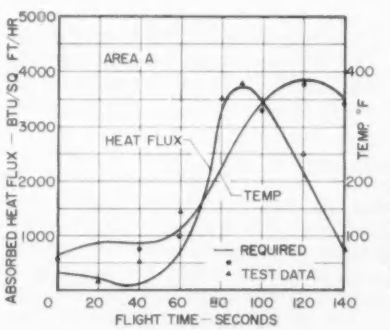


Fig. 5 — Comparison of the required heat flux and skin temperatures curves with those achieved by the programmer, shows good accuracy.

potential dividing circuit allowing the control signal to be varied from 0 to 28 v d-c. An interval timer working in conjunction with a rotary stepping switch controls the period of time in each step. This allows the desired test curve of heat or load, as a function of time, to be approximated by varying the excitation signal voltages of the actuators for predetermined time periods. The time period is preset through a series of resistance-capacitance networks in the interval timer circuit. A new RC network, capable of varying the time interval from 0.5 to 40 sec, is introduced in each step. Reversal of signal voltage in each step is accomplished by a polarity switch.

Calibration

Precalibration of both the heating and the loading system is necessary to establish a relationship between programmer output voltage and heat flux or pressure. Once established, these data provide the signal voltages which would be required to match any temperature-time and load-time curves. Although interpolation between signal voltage settings, and allowance for other variables are required, specified curves can be closely matched with only minor adjustments.

To calibrate the load control system, optimum cylinder size and operating pressures first have to be determined so that flight load curves can be converted into pressure curves. The load controller is then calibrated in terms of rate of pressure change to the load cylinder, as a function of time, for various signal voltages. The resulting curve is shown in Fig. 2. From this curve signal voltages are selected, with their associated time intervals, to reproduce the required flight load curves. The method of approximating the required curve with a series of variable length chords, is illustrated in Fig. 3. Ten chords are available with this programmer, corresponding to the ten steps per channel. Chord lengths are evidently determined by the period of time in each step as well as the magnitude of the signal voltage.

In tests involving the heat flux requirements, the required aerodynamic heat flux curves are first divided into short line segments (limited to 10) giving the best fit. The slopes of these segments are compared to those of the calibration curves (Fig. 4) and corresponding voltages are selected. These signal voltages with their associated time intervals are set into the programmer and, with some minor adjustment, produce good conformity with the required curves. Comparison of the required heat flux curves to the test data is given in Fig. 5.

Another application of this equipment is the reproduction of skin temperature as a function of time. This is done by calibrating the system to determine the time rate of temperature rise at various percentages of full power. The required temperature curves can then be simulated, as before, by choosing the proper power setting to give a rate of temperature rise similar to specific segments of the required curve. Power is varied by changing the resistance in the thyratron control network of the ignitron controller. The programmer is used to make the change.

To Order Paper No. 228A . . .
from which material for this article was drawn, see p. 6.

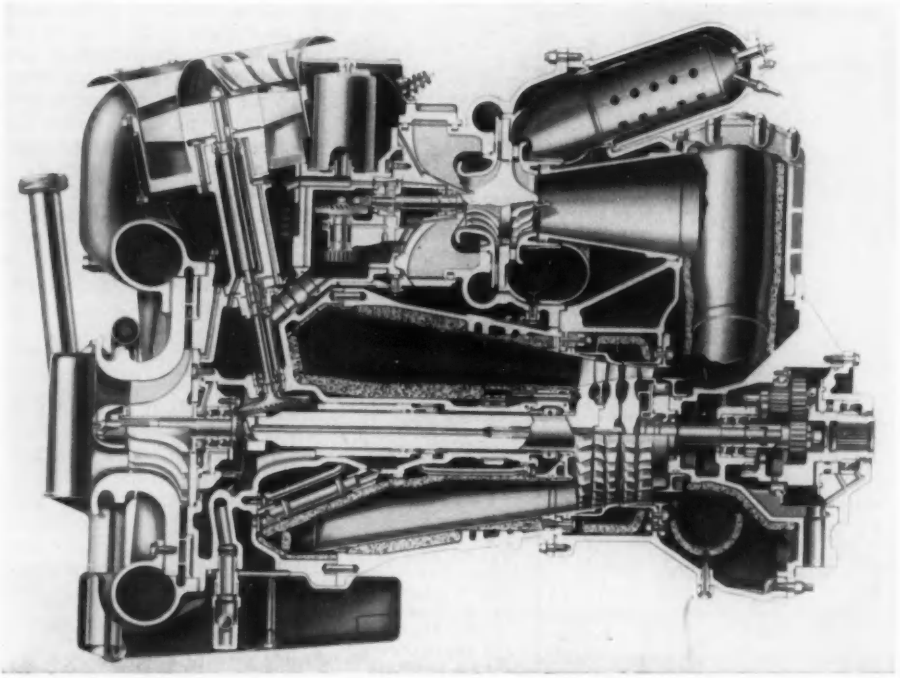


Fig. 1 — Cross-section of the **FORD 704 GAS TURBINE.** To get weight down without high cost, castings are used in preference to sheet-metal components.

FORD Gas Turbine . . .

. . . aimed to compete with heavy-duty truck diesels and spark-ignition engines. Design approaches objectives outlined in SAE Journal in September, 1960.

Based on paper by

I. M. Swatman

Ford Motor Co.

USE of stainless steel castings wherever possible, instead of hard-to-form stampings, reduces costs yet preserves desirable light weight characteristics in the Ford 704 gas turbine.

The main structural loads of the engine are carried by cast components with light sheet-metal ducts used within these castings only to guide the gases. In addition, the external castings contain the high-pressure air which reaches 220 psi at design load in this engine cycle. The rear casing of the engine performs this dual function as can be seen in Fig. 1. The other individual assemblies — the high-pressure spool, low-pressure spool, and the power turbine-bolt to this casing.

Problem of unequal thermal growth of the components was solved by a piston-ring-sealed sliding joint at the high-pressure compressor inlet. This allows differences in axial expansion between the low- and high-pressure compressor assemblies. Growth between the axial center lines of these components is provided for by a generous clearance between the diameter of the intercooler connecting duct and the high-pressure compressor inlet, the piston rings providing the air seal.

Low-pressure spool

The low-pressure spool, which is essentially the turbocharger, is an integral unit consisting of a two-stage turbine driving a single-stage centrifugal compressor at a design speed of 46,500 rpm. Fig. 1 shows the bearing design to be a two-bearing arrangement with a mid-shaft bumper bearing. The

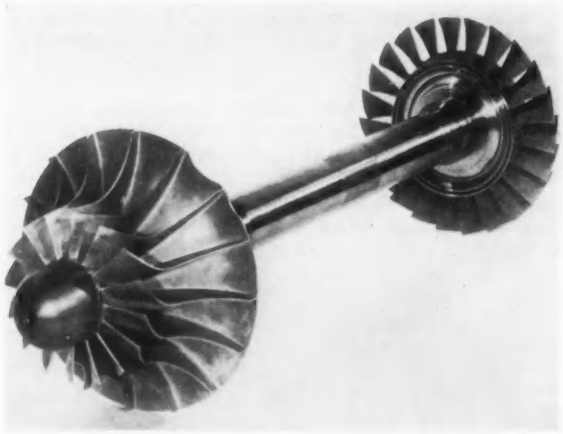


Fig. 2 — **COMPRESSOR WHEEL** is cast from C-355, T61 aluminum and spline-coupled to the shaft as shown in this assembly.

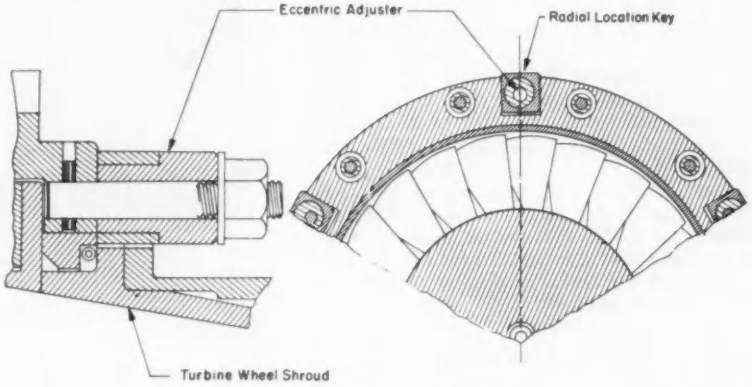


Fig. 3 — Liberal concentricity tolerances in the machining of **TURBINE SHROUD AND BEARING HOUSING COMPONENTS** are made possible by an adjusting device which provides for diametral growth of the turbine wheel shrouds.

bearing adjacent to the turbine wheel is a full-floating sleeve bearing. A similar design is used for the bumper bearing. Tandem, ball-thrust bearings are used adjacent to the compressor wheel, and a spiral bevel gear drive is provided for the intercooler fan.

Illustrative of casting use, the low-pressure spool consists of only one sheet-metal component which is the exhaust diffuser from the turbine wheel. Its other components are either aluminum or nodular iron castings or, in the case of the turbine shroud rings, fabricated from stainless steel, forged rings. The two turbine wheel stages are precision investment castings of Inco 713C alloy. The wheels are one-piece, integral blade-and-hub castings with the second-stage wheel hub flash-butt welded to an SAE 4140 shaft. Bearing areas are induction hardened and the C-355, T61 aluminum, cast compressor wheel is spline coupled to the shaft. The assembly is shown in Fig. 2. Interstage turbine nozzle blades and diaphragm are also a one-piece investment casting of Hastelloy *C*, with the shroud ring of the nozzle heli-arced through a ⅛-in. diameter hole to the tip of each vane.

Shroud concentricity adjustment

Provision for diametral growth of the turbine wheel shrouds, while maintaining blade tip clearance concentric with the axis of rotation, is provided by six radial slots in the flange of the turbin shroud ring located by six square keys bolted to the turbine case-support structure. A device for adjusting turbine tip clearance for concentricity at assembly is incorporated in the key mounting arrangement. This device, shown in Fig. 3, allows very liberal concentricity tolerances in the machining of the turbine shroud and bearing housing components.

Intercooler and its fan

The intercoolers are located between the scroll outlets of the low-pressure spool and the interconnecting duct to the high-pressure compressor inlet. A sheet-metal box forms a plenum between the two intercooler matrices and the fan discharges into the plenum chamber. The fan is an axial design with a sheet-metal prewhirl vane and turns at 18,200 rpm.

The cross-flow intercoolers are made by stacking

FORD Gas Turbine . . . continued

layers of corrugations and separator sheets. The material, zinc-clad 3002–0 aluminum, is furnace brazed to form the matrix assembly to which the headers are then attached by epoxy resin. Fig. 4 shows the assembly.

High-pressure spool

The high-pressure spool is a self-contained gas turbine unit. All accessories, oil pumps, fuel control, starter-generator are driven from the accessory gearbox of this section of the engine. Fig. 1 shows the rotating component to have a back-to-back configuration. The radial inflow turbine is an integral part of the compressor wheel, necessitated by the combination of stress and temperature in the turbine wheel. Heat transfer to the compressor wheel allows the turbine to operate at a higher tip speed and nearer optimum velocity ratio. At design speed, the unit rotates at 91,500 rpm. The power takeoff for the accessory gears is through a spiral bevel gear with a pitch-line velocity of 18,000 fpm. The gear is made of Nitralloy 135 with a flash coating of copper plate.

The compressor scroll and front shroud are nodular iron castings with the diffuser vanes machined as an integral part of the shroud. The nozzle vanes and diaphragm are a Hastelloy *C* investment casting, while the turbine scroll and shroud assembly are Hastelloy *C* stampings.

Power turbine and reduction gear

The power turbine is a single-stage unit rotating at 37,500 rpm. The output shaft is reduce to 4600 rpm by a planetary reduction gear. Concentricity of the turbine shroud over the wheel is achieved by radially pinning the Hastelloy *C* nozzle casting to the bearing housing and supporting the shroud from the tips of the nozzle vanes. The turbine wheel is an integral blade-and-wheel casting of Inco 713C with an SAE 4140 shaft flash-butt welded to the hub.

Gear reduction is through a planetary system us-

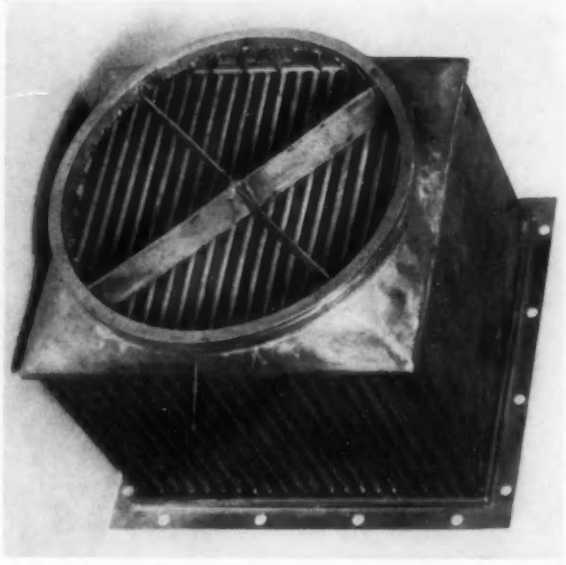


Fig. 4 — **INTERCOOLERS** are made by stacking corrugations and separator sheets which are then brazed to form matrix assembly. Headers are attached with epoxy resin.

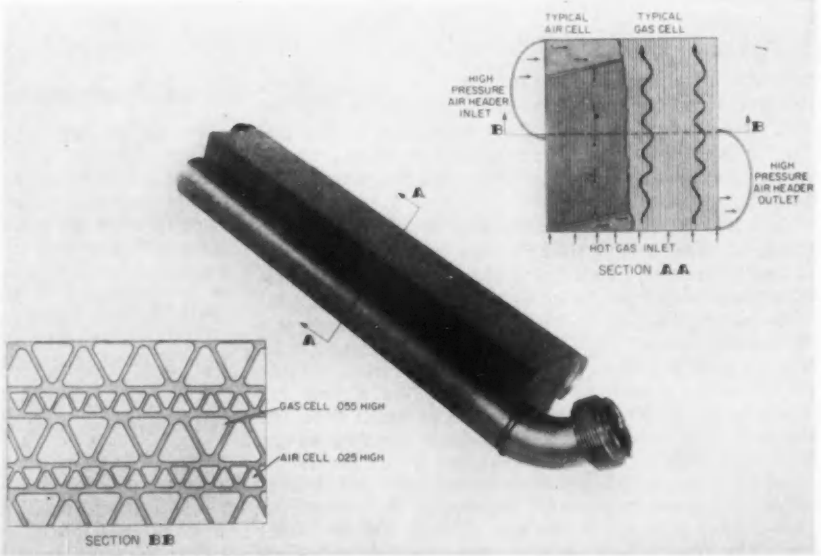


Fig. 5 — **RECUPERATOR MATRIX AND FLOW DIAGRAM OF FORD GAS TURBINE.** Matrix has Z-flow configuration proportioning flow area between cross flow and counter flow on the cool side of the matrix. Area ratio for air cell is 20-70-20.

ing the reaction of the planet pinions against a fixed ring gear to drive the planet carrier and output shaft. The carrier is mounted in two bearings which straddle the sun input gear on the turbine shaft.

Recuperator

Two headers are used to manifold the air to and from the recuperator matrix which is of Z-flow configuration (Fig. 5). The engine uses two units. The Z-type flow exchanger allows a portion of the flow to be in a counter-flow direction, resulting in a higher effectiveness for a given volume. Selection of the configuration involves proportioning of the flow area between cross flow and counter flow on the cool air side of the matrix. The 704 recuperator was selected with a 20–70–20 area ratio for the air cell. Distribution of the air within the cell to prevent thermal buckling and gain optimum effectiveness is achieved by curving the entrance to the corrugated separator within the air cell.

The matrix of 316 stainless steel is fabricated by stacking air cells and gas-side corrugations and furnace-brazing the assembly. The headers are attached by a second brazing operation after machining grooves in the matrix to locate the semi-circular manifolds.

Vehicle installation

Fig. 6 shows the 704 engine installed in a tilt cab truck. An air inlet duct with filtration and silencing system is installed from the cab grille to the compressor inlet. The air inlet for the intercooler fan is an integral duct built into the cab, sealing against the inlet guide vane when the cab is locked in down position. Exhaust from the intercoolers is allowed to blow under the cab mounting.

To Order Paper No. 291A . . .
from which material for this article was drawn, see p. 6.

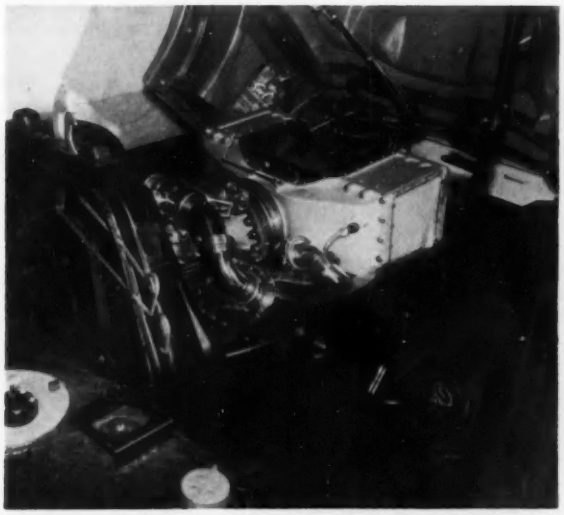


Fig. 6—Installation of the **704 GAS TURBINE IN A C-1100 TILT CAB TRUCK** shows its compact design. Only moderate changes were needed in vehicle structure.

Coating Prolongs X-15 Engine Life

Based on paper by

RAYMOND C. KOPITUK
Thiokol Chemical Corp

ADEQUATE protection of the spaghetti type combustion chamber of the X-15 rocket engine is achieved by coating the gas side of the chamber. The coating, a flame spray deposited Nichrome undercoat and a zirconium dioxide topcoat, helps prevent melting, severe oxidation, and erosion of the base metal.

This material has stood up well under conditions which are most severe even for a ceramic material. Hot gases flow on the outside of the tubes (within the combustion chamber), while the cold fuel flows inside the tubes, to provide regenerative cooling. The temperature gradient across the tube wall goes from 1300 F on the gas side down to 250 F on the liquid side where nucleate boiling of the fuel occurs. The gas velocity ranges from 500–800 ft per sec in the converging section to as high as 8500 ft per sec in the divergent cone. At the throat the velocity is 2500 ft per sec.

Without the protection of this special coating the tubes are subjected to oxidation, melting, and erosion. These mechanisms attack the tube walls until they are so thin that they rupture. With the protective coating applied failure, when it does occur, is the result of flaking away of the coating. However, engine life specification requirements can be met. Operation for as long as two hours has been achieved on some of these chambers.

■ **To Order Paper No. 280A . . .**
from which material for this article was drawn, see p. 6.

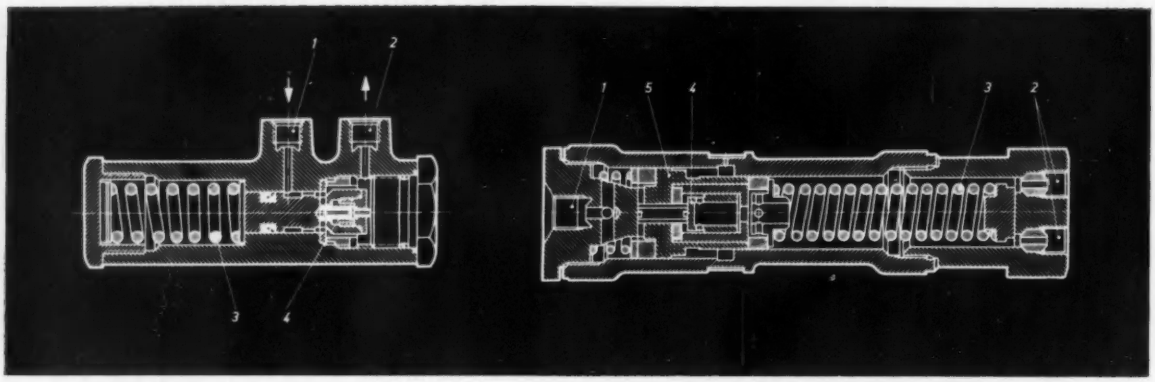


Fig. 1 — Brake pressure limiting valve (Alfred Teves) of a relatively simple type.

Fig. 2 — Brake pressure boosting valve used on Fiat 1500, 1800, and 2100.

Brake control devices

Based on paper by

Hans Strien

Alfred Teves Maschinen-and Armaturen-fabrik K.G. (Germany)

THE DANGERS of wheel locking can be minimized by the installation of a number of braking effect control devices developed in Europe during the past few years.

Some of these pressure limiting, pressure boosting, and pressure reducing control valves are described briefly in the following sections.

Braking pressure limiting devices

Fig. 1 shows a relatively simple limiting valve. It is connected at *1* to the master cylinder and at *2* to the line leading to the rear axle. Setting of spring *3* determines the limiting pressure on the rear axle and valve *4* takes care of proper release. Such a valve has been installed on the Dutch DAF passenger car because, when these vehicles were not fully loaded, there was danger of overbraking the rear axle. Today all European firms making hydraulic brakes have included in their manufacturing programs these or similar devices. For instance, the Renault Dauphine will be equipped with limiting valves.

Braking pressure boosters

In 1959 Fiat, after working along the same lines, introduced the booster shown in Fig. 2. It is now being used in the Fiat 1500, 1800, and 2100. This booster is installed between the master cylinder (connection *1*) and the front wheel cylinder (connection *2*). There is a direct connection between master and wheel cylinder up to a change-over pressure determined by spring *3*. At this moment valve *4* closes, so that differential piston *5* comes into action, boosting the pressure of the master cylinder to the front wheel cylinders.

Braking pressure reducing devices

Under certain circumstances it may be useful to reduce the pressure on the rear brakes. Fig. 3 shows such a stepless pressure reducing valve. Spring *1* is without tension and spring *2* is installed with a preload determining the changeover pressure. This pressure causes piston *3* to move, thereby closing the ball valve and stopping the flow. The further ratio of pressure increase in the master cylinder to increase in the rear wheel cylinders is determined by the differential areas of piston and ball valve seat, and by the ratio of the rate of springs *1* and 2. A progressive spring characteristic may also progressively change the pressure ratio, giving an even better approximation to the ideal distribution of braking effort between front and rear wheels. The characteristic of the valve is somewhat variable at

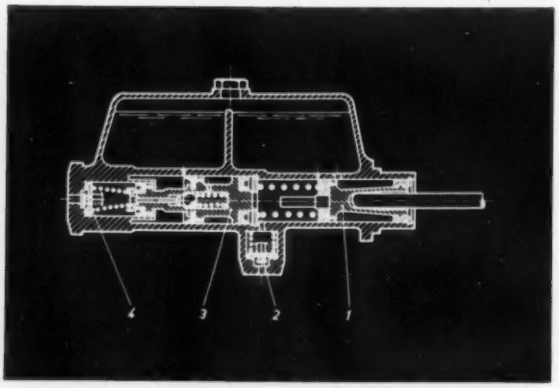


Fig. 5 — Combined tandem master cylinder and booster (Alfred Teves). Front part of tandem master cylinder can function as a pressure booster.

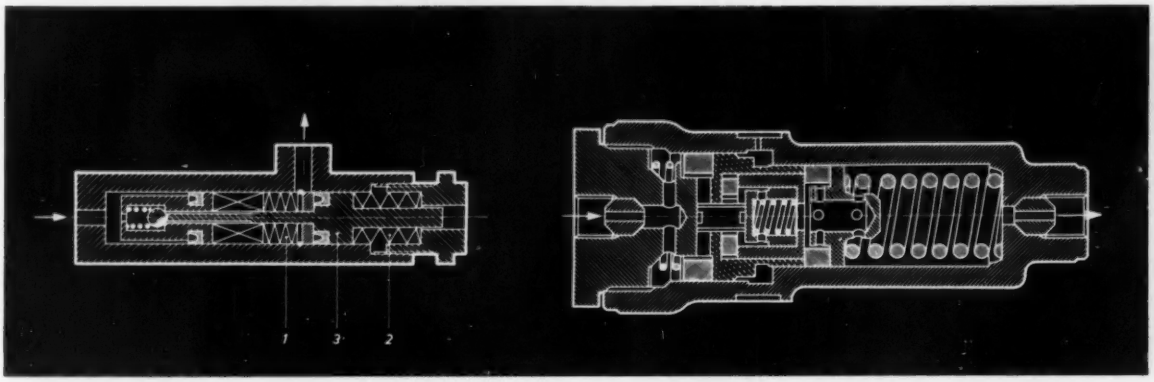


Fig. 3 — Stepless brake pressure reducing valve is used to reduce pressure on rear brakes.

Fig. 4 — Brake pressure reducing valve with uniform characteristic at increase and drop of pressure (if one does not consider the usual hysteresis).

minimize wheel locking

pressure increase and drop.

Fig. 4 shows a pressure reducing valve with a uniform characteristic at increase and drop of pressure — if one does not consider the usual hysteresis. Its function is based on the 2-diameter piston principle, similar to the booster shown in Fig. 3.

Combined braking systems and devices

In Europe 2-circuit braking systems are asked for again and again for use on certain types of vehicles. For this reason, we have designed the unit shown in Fig. 5, on which the front part of a tandem master cylinder can function as a pressure booster. The directly actuated piston *1* supplies pressure via the residual pressure check valve *2* at the end of the rear axle circuit. The front floating piston *3* is in the form of a compound master cylinder piston, which applies the same pressure via residual pressure check valve *4* to the front axle circuit as to the rear axle circuit, up to the lower change-over point. At this instant the pressure increases more at the front than at the rear brakes; when the upper change-over point is reached, then the full breaking pressure is available. In case of failure of one circuit, the directly actuated piston *1* engages mechanically either the floating piston *3* or the latter abuts against the housing. This device, therefore meets not only the requirements of a 2-circuit system but also those of an improved braking effort distribution. It is, however, not yet in production.

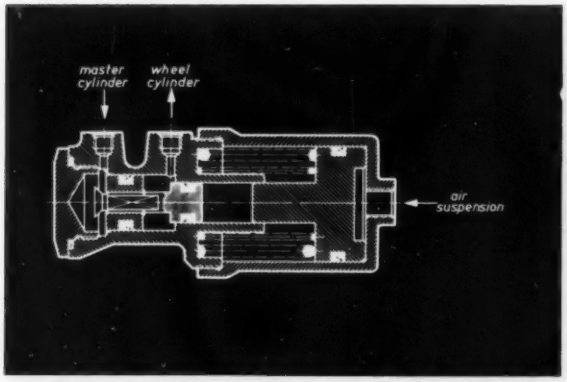


Fig. 6 — Brake proportioning valve with load dependent control. Proper dimensioning of the air cylinder diameter automatically permits the proper approximation, with increasing loading, of the practical braking effort distribution to the ideal distribution.

Load brake power compensation

The ideal distribution of braking effort between front and rear brakes for an empty vehicle (carrying only the driver) differs from that of the fully loaded vehicle. This can be taken into account in the devices shown in Figs. 2–4 by changing the preloading of only one spring. This will have the effect of raising or lowering the change-over pressure of the boosters or reducers. The change-over point could, in a primitive manner be changed even manually by arranging the proper valve behind the instrument board so that it could easily be operated with a control grip. Such a simple solution is, perhaps, suitable for a low-priced delivery truck, where the ideal distribution for empty and loaded conditions is like to vary to a rather large extent. A much better design, suitable for a modern passenger car, is now under development. It is shown in Fig. 6. The position of the change-over point of this brake proportioning valve, working on the booster principle, is determined by the pressure in the air suspension. A proper dimensioning of the air cylinder diameter automatically permits, with increasing loading, the proper approximation of the practical braking effort distribution to the ideal distribution.

To Order Paper No. 304C . . .
from which material for this article was drawn, see p. 6.

"Space-probing workhorse" is Saturn's destiny

Based on talk by

Dr. Wernher von Braun

Director, Marshall Space Flight Center,
National Aeronautics and Space Administration

Material drawn from an **SAE Detroit Section Talk**

THE GIANT SATURN, a multi-stage space vehicle standing 180 ft tall, is to become America's workhorse for space probing. The first version of Saturn, designated C-1, is a three stage, liquid-powered vehicle capable of orbiting 19,000 lb, or 9½ tons, of instrumentation into a 300-mile earth orbit. It will also soft-land a 1000–2000 lb payload on the moon, and release 5000 lb of payload from the earth's gravitational pull.

The Saturn C-2 project, a four-stage (plus payload), liquid-propelled vehicle, will permit orbiting a payload of 45,000 lb or 22½ tons.

The first stage of both C-1 and C-2, develops in excess of 1,500,000 lb of thrust or its equivalent of 32,000,000 hp. Each of the eight rocket engines, four rigid-mounted and four gimbal-mounted (for directional control), develop 188,000 lb of thrust or 4 million hp. The liquid oxygen and kerosene fuel are stored in the nine clustered tanks. Eight outer tanks (four fuel and four oxygen) are 70 in. in diameter and the center (liquid oxygen) is 105 in. in diameter. The first stage is 82 ft long and 21½ ft in diameter.

Numerous static tests of this stage have been conducted at the NASA test stand located at Redstone Arsenal. These tests have given opportunity to debug this stage, and it is now functionally acceptable.

The second stage of C-1 differs from the second stage of C-2, in that the C-1 stage consists of four Pratt & Whitney liquid hydrogen-oxygen engines developing 17,500 lb thrust each.

The C-2 second stage engine (and the C-2 third stage) is currently under development by Rocketdyne Division of North American Aviation. The stage will be powered by four, 200,000 lb thrust engines, burning liquid hydrogen and oxygen. Development of this engine has advanced to the battleship-type testing stage permitting non-flyable hardware to be tested for functional behavior.

The third stage of C-1 (and C-2 fourth stage) is a two-engine version of the C-1 second stage; namely, two 17,500 lb thrust engines of the Pratt & Whitney variety, burning liquid oxygen and liquid hydrogen. This stage is also known as the Centaur rocket, and is under development by Convair Division of General Dynamics Corporation.

Payload of C-1 and C-2 will depend on the mission of the individual shots. In C-1, the payload would generally be instrumentation. The C-2 payload, however, could be a manned capsule — in which case it would be sectioned to include a personnel compartment where the crew rides during the ascent — and a second section where space experimentation can be conducted; a utility "truck" providing fuel for orbital refueling maneuvers; or any other kind of utility "truck" providing space engines, food, and supplies for a lunar expedition.

The 21½-ft diameter and 82-ft long size of the Saturn first stage has caused NASA's scientists to design a Saturn barge, a cross between a barge and a blimp hanger, which will float the first stage (behind a river-going tug) down the Tennessee River to New Orleans, where a sea-going tug will tow the barge the rest of the way to Cape Canaveral.

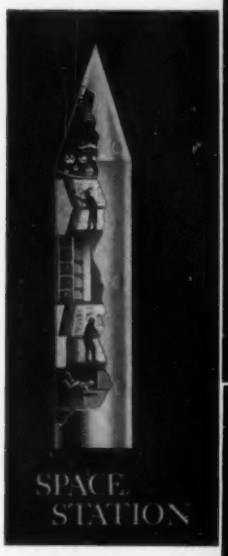
Another multi-million expenditure in the Saturn program is Pad 34, Cape Canaveral. The launch complex includes a service tower 310 feet high. This structure is equipped with a number of platforms which provide ready access to various stations in Saturn and a number of "arms" for fueling purposes, as well as providing electrical power to the stages prior to launch. Other structures include a fortified blockhouse instrumented to monitor and launch the vehicle; the launch pedestal; an umbilical tower; and fuel and oxygen storage facilities.

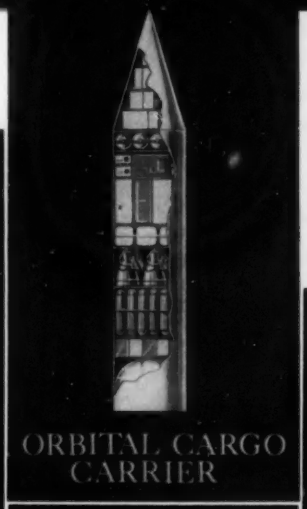
Dr. Wernher von Braun, whose career in space began when he was 18 years old — and whose accomplishments include development of the German V-2 and the U.S. Redstone and Jupiter ballistic missiles — now heads the team of scientists developing the Saturn space vehicles.

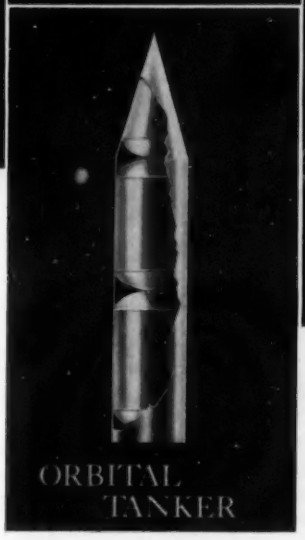
Trip-to-the-moon problems

There are many problems on a trip to the moon which must be taken into consideration. Merely to impact the moon, Saturn C-1, after building up to escape velocity and dropping stages 1 and 2, can continue in a predetermined trajectory which will intercept the moon. This direct approach was used in the Russian venture and the American attempts.

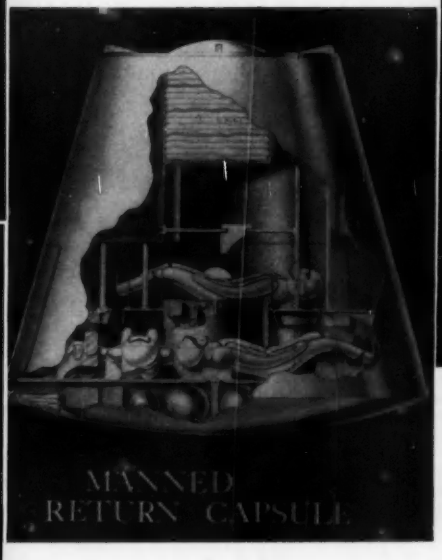
Soft-landing instrumentation will require that







The versatile Saturn's workload includes an array of tasks; all vital to future space endeavors. Proposed payloads for this workhorse are illustrated.



the payload package be turned around in space and the impact be retarded by retro-rockets. This project is within the capability of several vehicles, such as Atlas-Agena, Atlas-Centaur, and Saturn C-1 and C-2.

To soft land manned equipment and return it to earth is another problem. A vehicle producing 12 million lb of thrust would be required for such a venture. To circumvent designing such a tremendous rocket, orbital refueling is being considered. It would be accomplished in this manner: the manned capsule would be launched into a perfect earth orbit (i.e., apogee and perigee equi-distant from earth surface). Other Saturns, following in its wake at prescribed intervals, would rendezvous with the manned capsule, and the empty third and fourth stage tanks would be refueled by the Saturn tankers. This project could require approximately five Saturn tankers to refuel the empty third and fourth stages. Upon refueling, the astronauts would propel themselves to escape velocity and into a trajectory to intercept the moon. After the third stage burnout, the stage would be jettisoned. The fourth stage would serve as the retro-rocket, remain attached to the fifth stage, and serve as landing gear and launch pad for the manned capsule.

The fifth stage, utilizing solid or storable liquid propellants, would carry the passengers out of the lunar gravitation field and back into that of earth's.

A normal re-entry into earth's atmosphere would require placing the capsule into an eliptical orbit about earth, wherein the perigee of the orbit would lead intentionally into earth's atmosphere. At this stage of re-entry, the capsule would be traveling at Mach 24. The blunt end of the capsule, providing substantial drag and a stabilizing effect on the capsule, would be turned to face into the atmosphere, thereby reducing aerodynamic heating to a bare minimum. As the capsule descended to 15,000 ft and the angle of approach reached 60 or 70 deg, a parachute would open, carrying the capsule to earth.

Considering the cost of the moon "shots," the Saturn vehicles would reduce the cost of "orbital transportation" from the order of $10,000 to $500 per lb. Under evaluation presently is a "para-glider" scheme, which experts believe will make it possible to fire a Saturn booster out of Canaveral, make it turn around 180 deg, and cause it to land right back on a landing strip on Canaveral in 20 minutes.

The para-glider is strapped to the booster like a parachute and blossoms out under aerodynamic pressure in sensible atmosphere. The shroud lines are utilized for control. Linking power drives and winches to the shroud line, and operating these winches with electronic remote control, it seems possible to guide such a unit back to Canaveral base of operations. . . . And with booster recovery, the cost-per-payload-pound can be reduced something like $200 to $300.

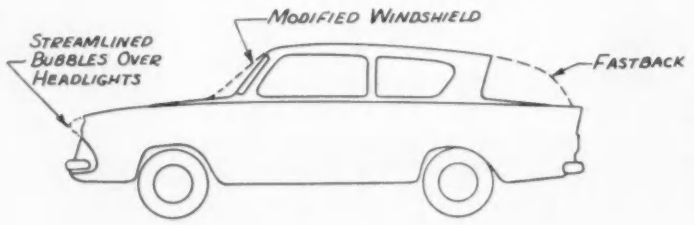


Fig. 1 — Streamlined 1960 Anglia. The indicated modifications were designed intuitively, with the result that only the windshield change produced a drag reduction. The addition of the fastback actually had a detrimental effect on drag.

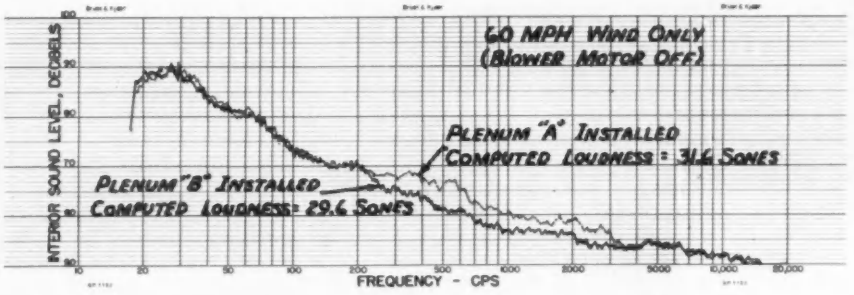

60 MPH WIND ONLY (BLOWER MOTOR OFF)
PLENUM "A" INSTALLED COMPUTED LOUDNESS = 31.6 SONES
PLENUM "B" INSTALLED COMPUTED LOUDNESS = 29.6 SONES
INTERIOR SOUND LEVEL, DECIBELS
FREQUENCY - CPS

Fig. 2 — The ventilation system of many automobiles often contributes to the "rushing" noise heard. In the particular heater plenum design tested in the wind tunnel, only minor changes were needed to improve the performance to that of plenum B.

"Hurricane Road" cures

Based on papers by

Charles A. Freeman, Jr.
William G. Cato and Jerome Meek
Thomas E. Dreaver and Edward L. Richardson
Ford Motor Co.

Material drawn from an
SAE Detroit Section Junior Activity Paper

SINCE vehicles do not rattle, rumble or do anything wrong while on the drawing board, deficiencies must be rapidly and accurately corrected as they occur in prototypes. Ford's approach to this problem is "Hurricane Road," a wind tunnel capable of producing extreme environment conditions for vehicle testing. Aerodynamic testing, the importance of which is magnified by today's high speeds, may be performed as well. Included among the diverse problems investigated are: influence of aerodynamic shape on fuel economy, engine cooling system development, and cures for wind noise.

Aerodynamics and fuel economy

It is well known that better aerodynamic design can reduce vehicle drag and give correspondingly increased fuel economy. However, intuitive streamlining "by eye" is inadequate. To illustrate this point, Fig. 1 shows the 1960 Anglia and indicates the placement of plastic attachments thought suitable for streamline improvement. Tests on Hurricane Road showed that the "fast back" insert in the notch behind the reverse slant rear window actually increased drag by 1%. The false windshield, though, reduced drag by 16%. This corresponds to 1 mpg increase in fuel economy at 40 mph. An increase in top speed from 72 to 76 mph also resulted from this modification. The bubbles on the headlights did not affect drag one way or the other.

Since the trial and error approach is indicated by these results, the wind tunnel is quite useful in this area. Before body configurations become fixed, aerodynamic tests on easily modified clay or plastic models can point the way to improved design.

Engine Cooling

This facility, having the ability to simulate environmental conditions, allows complete, accurate and repeatable simulation of road cooling. A radiant heat source is available for sun simulation and the dynamometer is adaptable for programming operations such as city traffic cooling. The sources of inconsistencies found in road tests can be controlled. During a road test, for example, even slight winds can significantly affect air flow through the radiator causing spurious results. Also, uncontrolled ambient conditions cause engine power to vary.

"Air-to-boil temperature," the ambient temperature at which boiling will occur, has become the measure of cooling performance. In the wind tunnel, however, it is not the practice to actually raise the ambient temperature until boiling occurs. Routine tests are performed with about a 20 F margin. The reason for this is that minor differences in en-

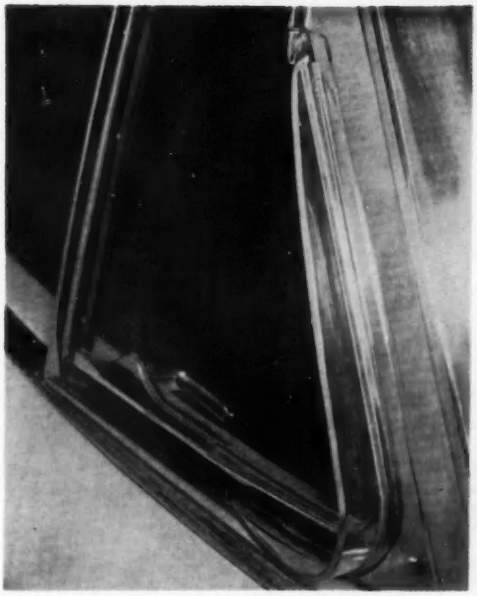


Fig. 3 — Cross vent window modification served to destroy the acoustic coupling between the two sides of the vent window. This effectively removed the "pumping" disturbance inside the vehicle.

many auto woes

gines of the same design would grossly influence the test results. A hot spot, for example, would result in severe local boiling and poor performance even though the average temperature was slightly below boiling. Cautious approach to the boiling temperature would be required to avoid overshoot and consequent loss of water.

Using the safety margin, air-to-boil temperature is calculated from stabilized temperature of top water, ambient air, and the boiling point with pressure cap. The air-to-boil temperature is less than the boiling point temperature by an amount equal to the excess of top water temperature over ambient air temperature.

Since the difference between top water temperature and ambient air is independent of air temperature level, the temperature at which the test is conducted will not alter the results. It is only necessary to maintain a constant engine efficiency and load. In the wind tunnel, load is constant since it is a set quantity. Engine efficiency is also constant because engine top water is also a set quantity.

The proper load for accurate wind tunnel testing is the load that would exist in road operation at the maximum air temperature to be encountered. This load can be determined by calculation or by road tests. To represent customer usage the grade load concept is used. Various combinations of grades and road speeds are selected to represent maximum sustained loads to which a customer might subject the vehicle. It is important to perform cooling tests at the proper loads. If, for example, the horsepower setting is high by 3 hp, the air-to-boil temperature will be in error by 3 deg. From the general approximation that one fin per inch must be added to give about 3 deg of extra cooling, the cost of such an error would be about 50¢ per unit.

Wind noise

Although wind noise can go unnoticed during a car ride, when it is suddenly reduced the change is quite noticeable, and pleasant. In modern vehicles noise does not cause immediate discomfort, but prolonged exposure can lead to mental weariness. Quiet operation is unquestionably desirable, and the wind tunnel is a useful tool for achieving it. In the tunnel, purely wind induced noises are isolated because the vehicle is not in operation. Accessibility to all parts of the vehicle is attained and wind and temperature variations do not affect test results.

Wind noise can be divided into three categories; the unpitched "rushing" noise, cavity resonance, and monotones or pitched noises. The unpitched noise is due to air passing over irregularities of the vehicle body surface. Heater and ventilation systems also often produce this same type of noise. At highway speeds, ram air alone can create objectionable sounds. The tunnel can quickly evaluate modifications of the duct system to eliminate areas of high turbulence or minimize resonances. Two heater plenum designs with ram air flow are compared in Fig. 2. Only a minor change was needed to reduce the sound levels in the rushing noise frequencies between 300 and 6000 cps, for design B.

Cavity resonance is a condition similar to that obtained by blowing over the open end of a bottle or jug. The automobile is like a jug with a low cavity resonance frequency. With the proper combination of window opening and speed, all vehicles suffer from this noise condition; some all too readily. One prototype vehicle tested suffered from such a condition due to vent window positioning. Although not exactly audible, passengers in the vehicle were aware of a "pumping" sensation. Reproduction of this condition in the wind tunnel quickly led to the fix shown in Fig. 3, which sharply reduced the low frequency sound. The problem was that the partially open vent windows served as the neck and mouth of a conventional Helmholtz resonator. The modification works to mismatch the acoustic impedance on either side of the vent window opening. The acoustic coupling is thus destroyed and the objectionable disturbance.

Monotones are very annoying even at low intensities. One prototype vehicle, suffering from a high-pitched whistle, was tested in the wind tunnel to find a cure. After the noise was reproduced, test personnel moving about the vehicle found the grille to be the culprit. The grille was composed of a long row of vertical bars. As the wind passed over them the edges of each bar tuned up together to produce the whistle "symphony." The fix adopted was the de-tuning of the grille bars from one another by application of random quantities of body deadener on their rear side.

To Order SP-195 . . .
from which material for this article was drawn, see p. 6.

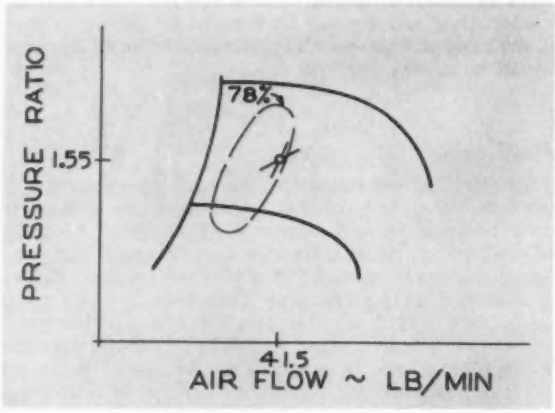


Fig. 1 — MATCHING TURBOCHARGER to constant speed engine. Peak compressor efficiency island is matched at the engine full-load operating point.

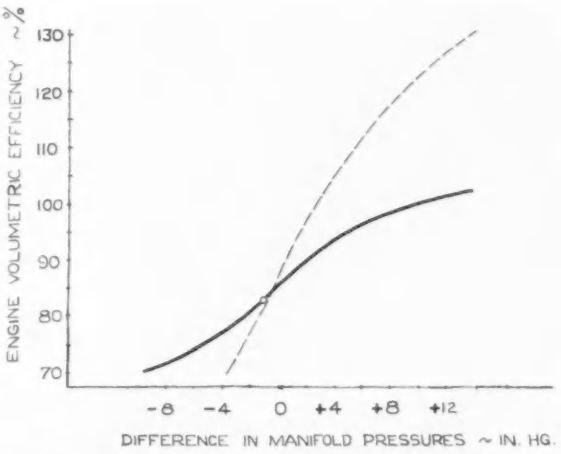


Fig. 2 — VARIATION OF ENGINE VOLUMETRIC EFFICIENCY with variation in engine manifold pressure differential. Dotted line represents high valve overlap engine, solid line low valve overlap engine.

Prerequisite for Turbocharger Design:

know your engine

Turbocharger designer must know the aerodynamic requirements of the engine application, as well as be able to develop efficient turbocharger components. Article gives examples.

Based on paper by

John M. Cazier and Wolfgang S. Lang

The Garrett Corp.

THE engine and its application influence the design of the turbocharger. It isn't enough for a turbocharger to have a compressor and turbine of high efficiency. Each component must be effectively matched to the specific operation of the turbocharged engine. This means that the turbocharger designer must know the aerodynamic requirements of the engine application, as well as be able to develop efficient turbocharger components.

The designer of the engine looks upon his engine as a heat machine. He tries to develop a mechanically sound engine with a combustion system which utilizes both fuel and air as efficiently as possible. The turbocharger designer looks at the engine in a different way: not as a heat machine but as a positive displacement air pump or airflow meter. However, he has no desire to alter the engine's combustion system features.

An engine of given speed and displacement can pump or meter a certain volume of air. Thus, at a given inlet air density, a metered flow of air by weight per unit of time is available for combustion of the fuel. We are after more weight flow of air so the engine can burn more fuel to produce more power. But we are dealing with volume machines: the engine, a positive displacement machine, and the turbocharger with a centrifugal compressor. The engine meters the flow from the turbocharger's centrifugal compressor. The actual volume of air the engine will flow depends on its swept volume and on its breathing ability, that is, its volumetric efficiency.

The volumetric efficiency of the engine is a function of its piston speed, port and valve design, manifold design, valve timing, and inlet and exhaust manifold pressures and temperatures.

The following example illustrates that engine output can be increased in two ways: increase in volumetric efficiency and increase in air density. The turbocharger can do both.

Engine air requirements — naturally aspirated

Assume a 4-cycle diesel engine of 750 cu in. displacement, operating naturally aspirated at 2300 rpm with a volumetric efficiency of 85% of its swept

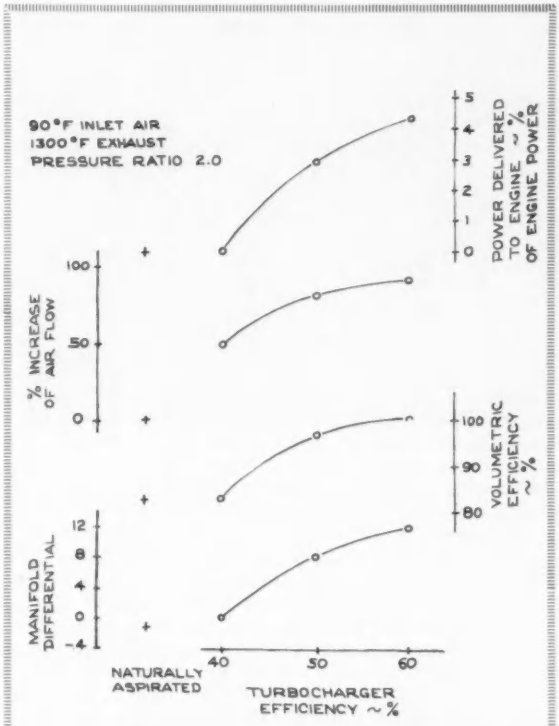


Fig. 3 — CUMULATIVE EFFECT OF CHANGES IN TURBOCHARGER OVERALL EFFICIENCY. As efficiency improves, a favorable manifold pressure differential is produced, which in turn improves the engine's volumetric efficiency, which increases the engine's airflow rate.

volume. This engine will flow $750 \times 2300/1728 \times 2 = 499 \times 0.85 = 424$ cfm. With an ambient air density of 0.07 lb per cu ft (the ambient conditions of the proposed SAE test code: 85 F, 28.77 in. of Hga, 50% relative humidity), the engine will flow 29.7 lb per min of air.

Assume a bsfc of 0.4 lb per bhp-hr at full load at a required air-to-fuel ratio of 20/1. Since this naturally aspirated engine has available 29.7 lb of air per min for combustion, it can burn 1/20 of this weight in fuel, or 89 lb per hr. This fuel rate at a bsfc of 0.4 lb per bhp-hr will produce a shaft output of 222 bhp.

To design a turbocharger compressor for the application, we begin with the engine's volumetric flow and calculate the air density change which the turbocharger's compressor must produce.

Turbocharged at constant speed

Assume that the engine is to be turbocharged to produce 310 hp, or 40% more than naturally aspirated power. Assume, too, that the engine's volumetric efficiency increases by turbocharging to 90%. This means that the compressor flow will be metered at a 6% higher rate of 449 cfm at engine inlet conditions. To produce 40% more power, the engine must burn 40% more fuel at the same 20/1 air-to-fuel ratio. Thus, 40% more weight flow of air, or a total of 41.5 lb per min, must be provided by the turbocharger's compressor. The volume flow of 449 cfm is fixed by the metering effect of the engine; so, the only way to provide the increased weight flow is by an increase in the density of the air delivered to the engine. An air density of 0.0925 lb per cu ft is required to produce the weight flow of 41.5 lb per min at the volume flow of 449 cfm. Since the ambient density is 0.07 lb per cu ft and engine inlet manifold air density must be 0.0925 lb per cu ft, the compressor must produce the change in density. So, a compressor density ratio of $0.0925/0.07 = 1.32$ is required.

By examination of possible compressor maps, we select a compressor design and determine the combination of pressure ratio and compressor efficiency which will produce the required density ratio.

Assume that a compressor is designed to provide an efficiency of 78% at the operating point. At this efficiency, the compressor will produce the required 1.32 density ratio at a 1.55 pressure ratio; therefore, the compressor discharge pressure delivered to the engine inlet manifold will be $28.77 \times 1.55 = 44.6$ in. Hga or 15.8 in. Hgg. Fig. 1 shows this simple matching at constant engine speed with the peak compressor efficiency island matched at the engine full load operating point.

The volume, pressure, and efficiency relationships of the engine and turbocharger are completely tied together. As shown by the example, the 40% increase in air weight flow is provided at the given manifold pressure, at the given volumetric efficiency, and at the given compressor efficiency. A change in any one of these values affects all of the others.

The variations in basic matching determinants are significant. Higher compressor efficiency means lower compressor pressure ratio for a given density ratio. Higher overall turbocharger efficiency, that is, high compressor and mechanical efficiency, reduces the turbine output to drive the compressor with the minimum expense of engine exhaust energy or minimum engine exhaust back pressure and temperature. This produces the highest pressure differential from engine inlet manifold pressure (compressor discharge) to engine exhaust manifold pressure (turbine inlet). This highest favorable differential pressure across the engine will increase the engine's breathing ability, that is, its volumetric efficiency, and promote scavenging. There will be, in addition, a decrease in engine pumping work.

Fig. 2 shows the shape of the variation of engine volumetric efficiency with variation in engine manifold pressure differential. The two lines, one steeply sloping for a high overlap engine and one of moderate slope for an engine with low valve overlap, show that the turbocharger designer has to be concerned with changes in volumetric efficiency.

Fig. 3 shows, for a single operating condition, the cumulative effect of changes in turbocharger overall efficiency. As efficiency improves, a favorable manifold pressure differential is produced, which in turn improves the engine's volumetric efficiency, which in turn increases the engine's airflow rate. This increase in airflow rate can be used either to burn more fuel at the same combustion efficiency or to increase the combustion efficiency to decrease fuel

Prerequisite for Turbocharger Design:

know your engine

. . . continued

consumption. The increasing manifold pressure differential delivers pneumatic power to the engine which the engine utilizes as a decrease in pumping work.

The principle to keep in mind as regards the effect of efficiency of turbocharger components is that the turbocharger is an integral part of the engine's thermodynamics. All energy handled by the turbocharger comes from the engine's fuel. Each improvement in efficiency in the turbocharger, just as anywhere else in the engine, produces an improvement in the turbocharged engine's thermal efficiency.

So far, the compressor requirement has been considered only for turbocharging a constant-speed engine. Most small turbochargers are developed for variable speed, variable load, variable location applications such as vehicle and construction equipment engines. This demands high turbocharging component efficiency over a wider range of compressor and turbine operation on the engine. A turbine with its peak efficiency matched to the peak efficiency of the compressor at the engine's full speed and load will give excellent performance at that point but it is doubtful that it will perform at two-third or one-half engine speed, or even allow operation of low engine speed, because of the surge limit of the compressor.

Where good lugging characteristics are of prime importance, a different performance is demanded from the turbocharger. The emphasis is on operation at part engine speed. The peak turbine efficiency has to coincide with the peak compressor efficiency at part engine speed and lower specific flows.

Turbocharging vehicle engines

Assume that the same engine is used as in the previous example but that the torque peak is desired at 65% engine speed or 1500 rpm. At this speed, with an engine volumetric efficiency of 90%, the volume flow metered by the engine will be 65% of the 449 cfm at 2300 rpm, or 292 cfm.

If the engine at 2300 rpm developed a bmep of 142 psi and a 10% torque rise is required at 65% speed, the bmep has to be 156 psi. This comes to an output of 221 bhp at 1500 rpm.

We still need an air-to-fuel ratio of 20/1 for clean combustion. Because of the combustion time factor, we assume the bsfc will improve to 0.385 lb per bhp-hr. With a fuel flow rate of 85 lb per hr or 1.415 lb per min we need 20 times this much air, or 28.3 lb per min, to satisfy this peak torque use.

Again taking a compressor design with 78% peak efficiency, a compressor pressure ratio of 1.58 will provide a density ratio of 1.34 for an inlet manifold density of 0.0935 lb per cu ft, which will give the required weight flow of 28.3 lb of air at the metered volume flow of 292 cfm at 1500 rpm.

For lugging operation, a turbocharger of different characteristics would be designed to satisfy the different engine needs. The compressor would be designed to supply the airflow requirements of peak engine torque in the peak efficiency island of the compressor, with sufficient margin to operate at this low engine speed without getting too close to the compressor surge limit.

The turbocharger is designed to give required performance at 65% engine rpm. When the engine speed is increased to 100%, the metered airflow will increase, and with this higher exhaust gas flow through the turbine nozzle the velocity of the turbine vortex will increase, resulting in a higher turbine speed; that is, with the increase in engine speed, the turbocharger speed will increase and result in a higher compressor pressure ratio at the full load point than is required, or perhaps even desired.

Several factors act to limit this increase of turbocharger speed. To produce high torque at part speed the turbocharger's compressor and turbine were designed to operate at peak efficiency at that part speed. With the increase of engine speed, the compressor and turbine efficiency will decrease resulting in a lower overall turbocharger efficiency. This means lower volumetric efficiencies and a lesser increase in flow. Exhaust temperatures may also decrease because of increased air-to-fuel ratios. Designing the turbocharger for divided exhaust manifolding of small volume is sometimes desirable. Since the engine blowdown or pulse energy is a large proportion of the total exhaust energy, at lower pressure ratios more benefit can be derived from pulse energy utilization at part engine speeds where it is most needed for high engine torque than at high engine speeds where pressure ratios tend to be higher.

If intercooling is added to the turbocharged engine, it will further increase the flow range required of the compressor.

With a turbocharger designed to provide enough air for a peak torque point at low engine speed, high turbocharger pressure ratios and therefore high engine inlet manifold and compression pressures are produced at full engine speed and load. A control system has been developed to modulate this natural characteristic of a "free-floating" turbocharger, to better provide the air required for high torque performance. Fig. 4 shows this pressure ratio control system.

The control system includes a controller which senses compressor pressure ratio. The controller signal causes an actuator to modulate a poppet valve which bypasses exhaust gas around the turbine, thus controlling its output so as to maintain constant compressor pressure ratio over a wide range of engine operating conditions. This control makes it possible to use smaller nozzle areas to obtain required compressor pressure ratios at low engine speeds at high torque rises without incurring excessive intake manifold pressures at high engine speeds.

The compressor pressure ratio selected for the controller can be set to stay constant or variable over the controlled range to accommodate the desired characteristics or compensate for altitude.

Fig. 5 shows the different compressor design requirements for free-floating, nonintercooled operation and pressure-ratio-controlled operation with intercooling. These operating lines show why the turbocharger engineer designs different compressors for these different modes of operation.

Other factors which affect aerodynamic design

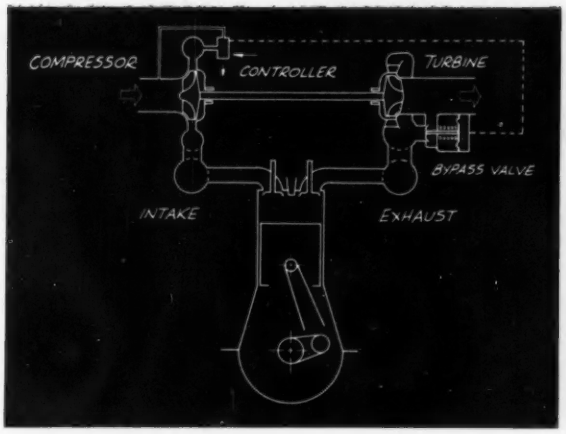


Fig. 4 — PRESSURE-RATIO-CONTROLLED TURBOCHARGER provides the air required for high torque performance.

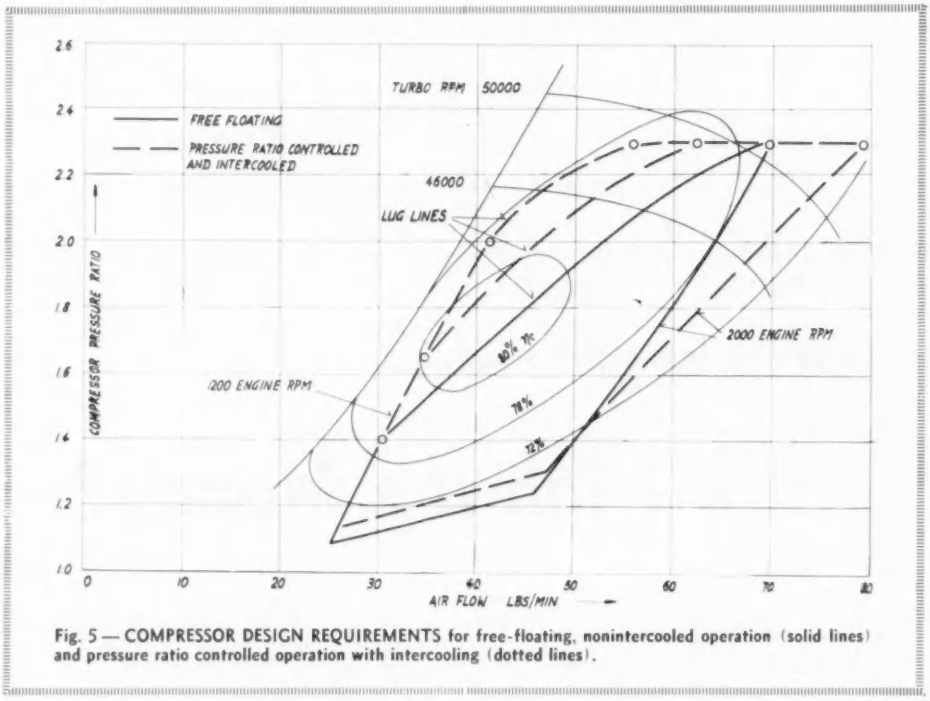


Fig. 5 — COMPRESSOR DESIGN REQUIREMENTS for free-floating, nonintercooled operation (solid lines) and pressure ratio controlled operation with intercooling (dotted lines).

requirements of the turbocharger include installation factors, ambient air pressure, and temperature variations.

We have assumed the standard SAE air density of 0.07 lb per cu ft at the compressor inlet. Pressure loss through the air cleaner and heating of the inlet air will change the aerodynamic requirements of the turbocharger. Restriction of the turbine exhaust by too small an exhaust stack will reduce turbine output.

With increase in operating altitude, the turbocharger will compensate for about two-thirds of the drop in ambient air density. (This compensation varies with the turbocharger's overall efficiency.) The compressor weight flow will decrease as a function of the drop in ambient density, requiring less turbine power to drive and decreasing air-to-fuel ratios. The turbine will see the lower ambient discharge pressure and increasing exhaust temperature, thus increasing its speed. These factors result in an empirical value of turbocharger speed increase of about 2% per 1000 ft increase in altitude. Also, the turbocharger often can be designed to overcharge the engine at sea level with sufficient excess air so that the engine will not feel the loss of ambient density at the required altitude. This requires that the turbocharger have enough design strength margin for its increased speed at altitude.

To Order Paper No. 257B . . .
from which material for this article was drawn, see p. 6.

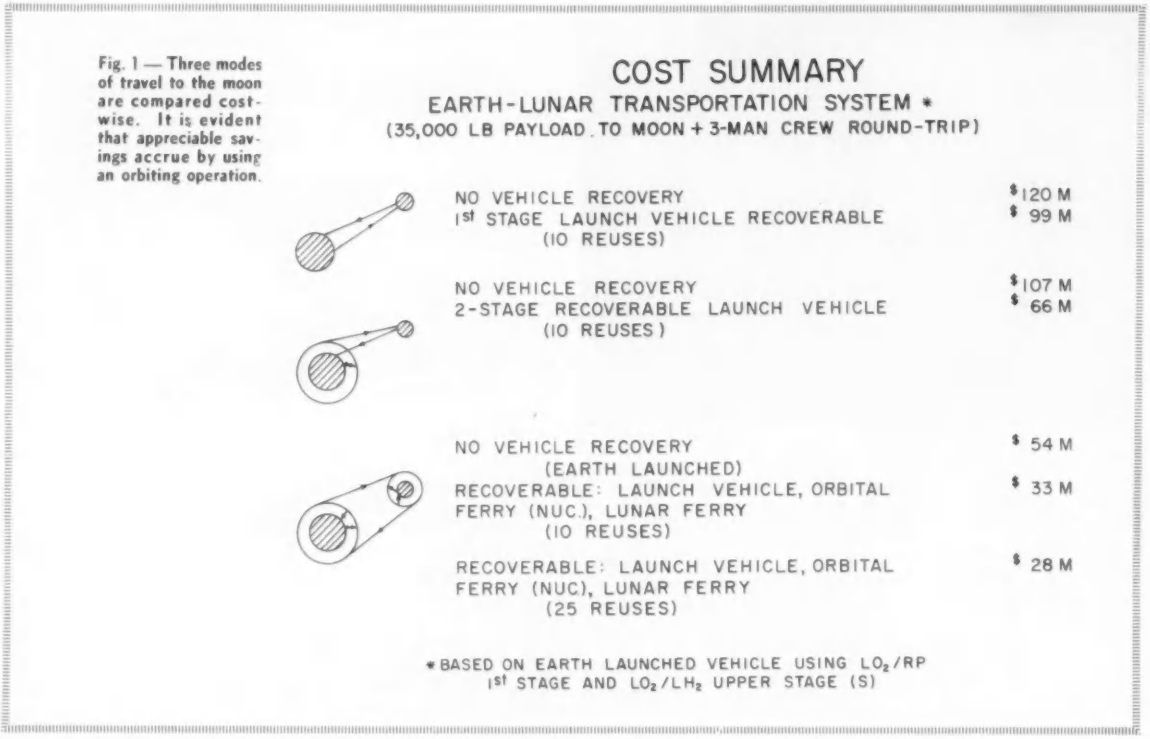

COST SUMMARY
EARTH-LUNAR TRANSPORTATION SYSTEM *
(35,000 LB PAYLOAD TO MOON + 3-MAN CREW ROUND-TRIP)
NO VEHICLE RECOVERY $120 M
1st STAGE LAUNCH VEHICLE RECOVERABLE $ 99 M
(10 REUSES)
NO VEHICLE RECOVERY $107 M
2-STAGE RECOVERABLE LAUNCH VEHICLE $ 66 M
(10 REUSES)
NO VEHICLE RECOVERY $ 54 M
(EARTH LAUNCHED)
RECOVERABLE: LAUNCH VEHICLE, ORBITAL FERRY (NUC.), LUNAR FERRY $ 33 M
(10 REUSES)
RECOVERABLE: LAUNCH VEHICLE, ORBITAL FERRY (NUC), LUNAR FERRY $ 28 M
(25 REUSES)
* BASED ON EARTH LAUNCHED VEHICLE USING LO2/RP
1st STAGE AND LO2/LH2 UPPER STAGE (S)

Fig. 1 — Three modes of travel to the moon are compared cost-wise. It is evident that appreciable savings accrue by using an orbiting operation.

Almost everything has a price tag, but . . .

How High the Moon's?

Here are some estimates.

Based on paper by

F. L. Williams, H. O. Ruppe, and R. G. W. Reichert

George C. Marshall Space Flight Center, NASA

AN ECONOMICAL approach to lunar flight is offered by orbital operation utilizing recoverable launch vehicles, rather than the direct approach. Fig. 1 demonstrates this by comparing estimated costs for three modes of lunar travel, with and without recoverability. The least expensive method is shown in case (c), where both earth and lunar orbits are used.

Three vehicles are used to perform this trip. One vehicle would be an orbital carrier to go from the earth's surface to an earth orbit, and back again on the return. A second vehicle serves as a ferry between the two orbits, while a third acts as a local lunar taxi to go from the lunar orbit to the lunar surface, and back again.

Another alternative to the direct approach is shown in case (b), where the vehicle is boosted into an earth orbit before going to the moon. The return trip is made directly to earth. The direct lunar flight is illustrated in case (a), and is seen to be the most expensive. Here the flights to and from the moon are direct, with no intervening orbital operation.

Orbital operation permits refueling, assembly, and vehicle checkout in space, thus overcoming the undesirable features of refueling or assembly on the moon. Besides being economical, it offers almost unlimited possibilities for delivering very large pay-

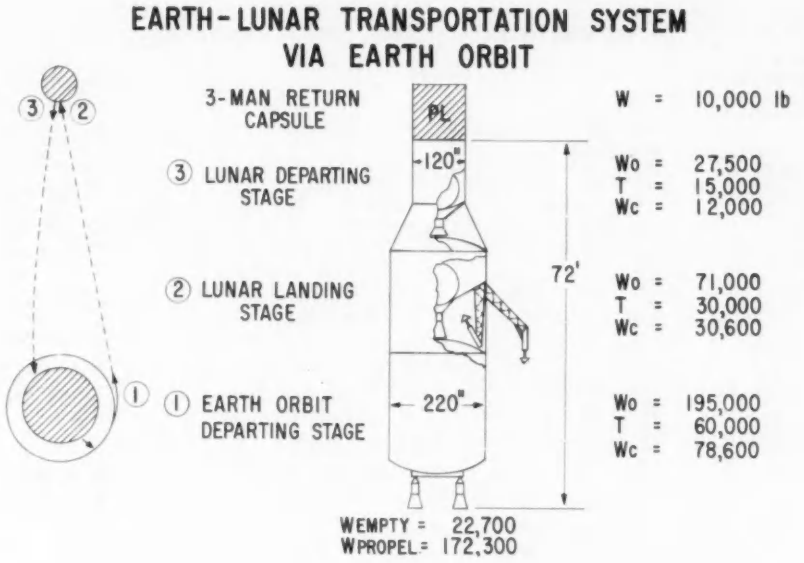


Fig. 2 — This vehicle once it is placed in orbit about the earth has the capability of going to the moon and returning directly back to earth. If no return trip is called for, the lunar departing stage can be replaced by cargo. The notations have the following meanings: w_o = lift-off wt w_c = cutoff wt and T = thrust.

Table 1 — Orbital Transportation Cost
Delivered to 300 N. Mi. Orbit

Vehicle	Payload Capability (lb)	Vehicle Cost, Launched (Million $)	Re-Flight Cost (Million $)	Transportation Cost ($/lb) 10 Reuses of Stage (S)	Transportation Cost ($/lb) 25 Reuses of Stage (S)
3 Stage Expendable	70,000	16.4	16.4	234	234
2 Stage Expendable	62,000	13.7	13.7	221	221
2 Stage (1st Stage Recoverable, 2nd Stage Expendable)	60,000	15.0	10.0	175	170
2 Stage (1st Stage Recoverable, 2nd Stage Recoverable)	50,000	16.5	5.5	132	119

loads to the moon or planets, with only moderate-size launch vehicles.

Cost of orbiting

The costs (excluding payload) of four different orbital carrier vehicles are shown in Table 1. For the expendable vehicles, the reflight costs would be the same as for the first flight, since a completely new vehicle is required. Where recoverable stages are used the expenditures are reduced to refurbishment costs. Launching costs remain the same for each use, and the small propulsion unit for the payload kick maneuver must be replaced.

By 1970, it is expected that 10 reuses will be well within the state of the art, and that 25 or so reuses will be feasible. The use of recoverable vehicles to this extent, can cut orbiting costs in half.

Moon via earth orbit

A three-stage vehicle to carry three men in a 10,000-lb capsule, from an earth orbit to the lunar surface (case (b)), is shown in Fig. 2. This craft

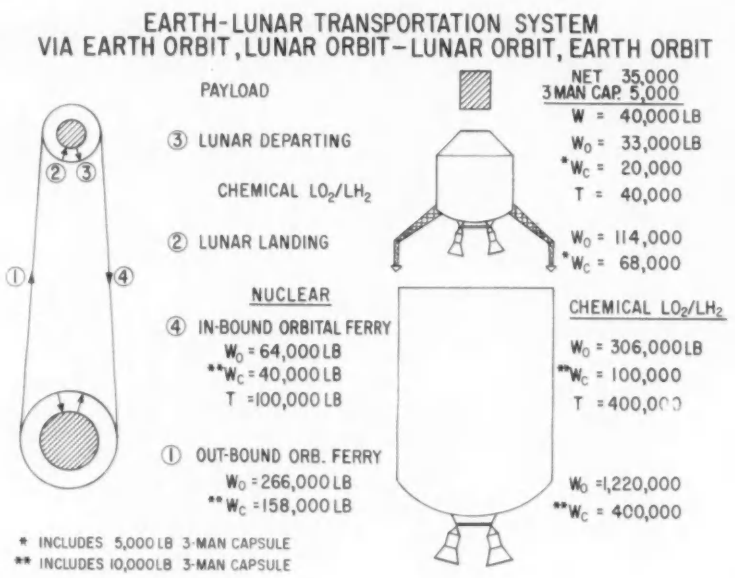


Fig. 3 — The orbital ferry and local lunar taxi, shown above, combined with the orbital carrier vehicle provide the most promising mode for lunar travel. In this particular study a nuclear and a chemical source of power are compared.

How High the Moon's?

. . . continued

would also be capable of returning at any reasonable time after landing. If no return trip was desired, 27,500 lb of useful payload could be soft-landed on the moon. This replaces the lift-off weight of the third stage which, when used, imparts lunar escape velocity to the vehicle.

The first stage provides the velocity needed to escape from the earth orbit, and the second stage accomplishes the lunar landing maneuver. All stages are powered with LO_2/LH_2 propellants, which were determined to be quite economical.

Space taxi technique

Using both earth and lunar orbits results in a more flexible transportation system. The vehicle is shown in Fig. 3. Three men can be carried, along with 35,000 lb of cargo. Also, since the manned capsule for the lunar landing and departure do not require heavy shielding for atmospheric re-entry, the capsule weight is reduced to 5,000 lb for this portion of the trip.

Based on these assumed weights the trip from the earth orbit to the moon would be carried out in the following manner. The orbital taxi performs the transfer between the two orbits. It is required to deliver, to the lunar orbit, the three men (in a 10,000 lb capsule), 35,000 lb of cargo, and the propellant (59,000 lb) for the local lunar ferry, as well as its own propellants. Two types of propulsion systems are compared in Fig. 3, one using nuclear power and one using LO_2/LH_2. The weight of the nuclear vehicle is only ⅓ that of the chemical version:

- Lift-off Weight of Nuclear System = 30,000 lb + 10,000 lb capsule
- Lift-off Weight of Chemical System = 90,000 lb + 10,000 lb capsule

In the long run the nuclear system will also be cheaper.

Once in the lunar orbit, the lunar landing and departing vehicle would take over. This vehicle is brought into its lunar orbit by first being boosted into an earth orbit by the previously mentioned orbital carrier. There it is refueled so that it may fly itself into a lunar orbit, where it arrives with its propellants depleted. To accomplish the flight to the lunar surface and back to the lunar orbit, the vehicle is refueled in its orbit by the orbital taxi.

Both the orbital taxi and the local lunar ferry are one stage vehicles, thereby avoiding the use of expendable hardware.

Direct approach

For the direct approach, recovery of the first stage can be considered, but second stage recovery is not feasible. This is because re-entry occurs some 2000–3000 mi down range, under extreme conditions of temperature and dynamic pressure. But even without the advantage of launch vehicle recovery, the orbit-to-orbit method is more economical by a factor of two.

To Order Paper No. 302J . . .
from which material for this article was drawn, see p. 6.

Round trip to the Moon for $600

Add indirect cost and tips to this direct cost and it is still cheap, isn't it?

Based on paper by

M. W. Hunter

Douglas Aircraft Co., Inc.

TRAVEL to and from the moon need not be excessively expensive. If high-energy, recoverable systems were used in place of conventional chemical propulsion, it would save a lot of money; if nuclear recoverable rockets were used, travel would be still cheaper.

It is conceivable that the cost in dollars per pound in cargo delivered each way would drop to as low as $1/lb with nuclear systems, and the economy of the rockets would amortize development costs rapidly. When analyses of direct operating costs are applied to passenger transportation, it is found that a round trip to the moon could run as low as $600 per passenger. This figure includes cost of pilot, stewardess, and food, but not the ticket price which would include indirect costs.

Why nuclear systems are attractive

Fig. 1 shows the gross weight-to-payload ratio for a lunar transport using atmospheric braking on return to earth. With a rocket using current chemical engines, the gross weight-to-payload ratio will be well over 1000 and many stages will be needed. If high-energy chemical propellants are used, this ratio will be somewhat over 100 and it may be possible to use only three stages. A nuclear rocket, on the other hand, will have a ratio of about 10 and a single-stage device might suffice. It's the low gross weights with single-stage devices that make nuclear systems so attractive.

The possibilities of economic use of a single-stage spaceship hinges on making the vehicle reusable in the manner of a normal aircraft. A DC-8 airframe,

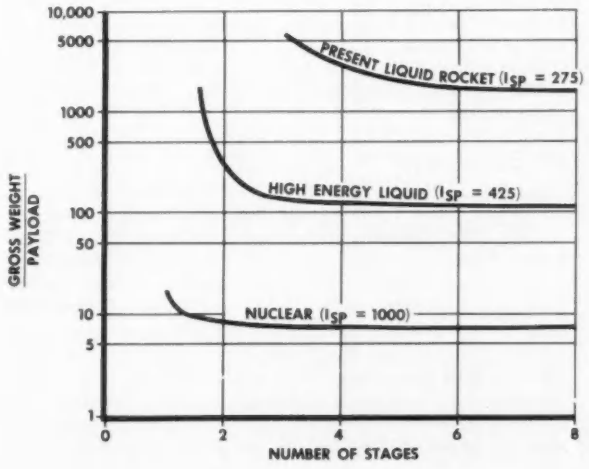


Fig. 1 — Gross weight-to-payload ratio for three lunar transport propulsion systems with atmospheric braking. Impulsive velocity is 60,000 fps.

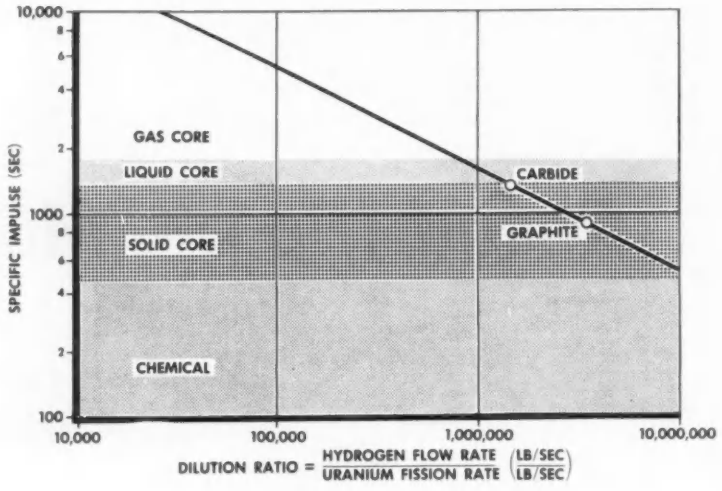


Fig. 2 — Specific impulse available from fission reaction shown as a function of dilution ratio indicates desirability of developing gaseous core reactors.

Round trip to the Moon for $600

. . . continued

for example, is expensive but its price is amortized over a large number of flights so that the effect of its initial cost upon direct operating costs is almost negligible. A similar reduction in vehicle expense for space flight is desirable but unlikely to be achieved with large, multistage rockets. Even if the rockets were completely recoverable, the stages would be strewn about the planets and on orbit during launch and landing, and would have to be returned to the next launching site. It is hard to believe that recovery costs would be lower than those achieved by a single-stage vehicle.

Significance of fuel costs

Typical chemical fuel costs in future production can be expected to be of the order of 2¢/lb for RP-1 and liqiud oxygen, and 25¢/lb for liquid hydrogen. Average propellant costs for conventional propulsion systems are then 2¢/lb, and 4–5¢/lb for hydrogen-oxygen systems. The price of nuclear rocket fuel depends upon the relative amount of hydrogen and uranium used, hence upon the specific impulse at which the rocket works.

The specific impulse available from fission reaction is shown in Fig. 2 as a function of dilution ratio which is the working fluid flow rate divided by the uranium fission rate. At a specific impulse of 1000 sec, over 1,000,000 lb of hydrogen are used per pound of uranium fissioned. Thus the amount of uranium used is very small. A decrease in dilution ratio is accomplished by an increase in source temperature which has to be achieved through advances in reactor and propulsion technology. Use of either liquid or gaseous core reactors should be considered to extend the temperature limits characteristic of solid core reactors.

Nuclear propulsion wins

Using the curve in Fig. 2 from which to derive the total propellant cost, assuming 25¢/lb for hydrogen and $5000/lb for uranium, we find that at 1000-sec specific impulse the price of uranium burned is essentially negligible compared to hydrogen, being less than 1¢/lb. Then, if we take only the chemical cost estimates of the nuclear fuel costs and apply them to vehicle gross weights shown in Fig. 1, we find that even at the very low price per pound of fuel and oxygen, the gvw is so high that fuel costs will amount to over $40/lb of payload regardless of any other costs of operation. With high-energy propellants the fuel cost would be $6/lb of payload, while nuclear propulsion propellant costs would be near $2/lb.

Hardware costs

Estimates have been made of the price of hardware involved in payload delivery, again working from Fig. 1. For chemical rockets hardware weight varies between 5 and 8% of the propellant weight as a function of number of stages. For a nuclear rocket this number runs between 10 and 15% of the fuel weight. Assuming $30/lb for structure and $100/lb for engines, we get Fig. 3 which shows that for nonrecoverable hardware the cost in dollars per pound is extremely high, even for single-stage rockets. The only hope is recovery and reuse of the vehicles. If reused only 25 times, the hardware cost is acceptably

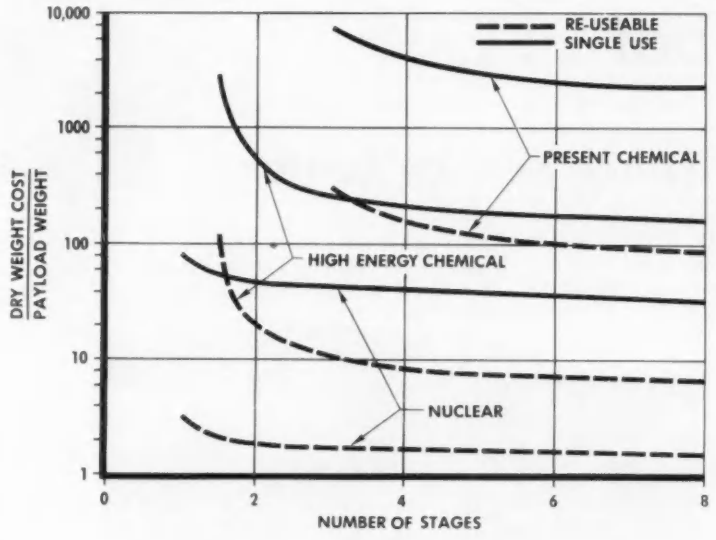


Fig. 3 — Hardware cost for lunar round trip shows recovery and reuse of vehicles to be essential to reduce costs. A nuclear, single-stage rocket has a decided edge.

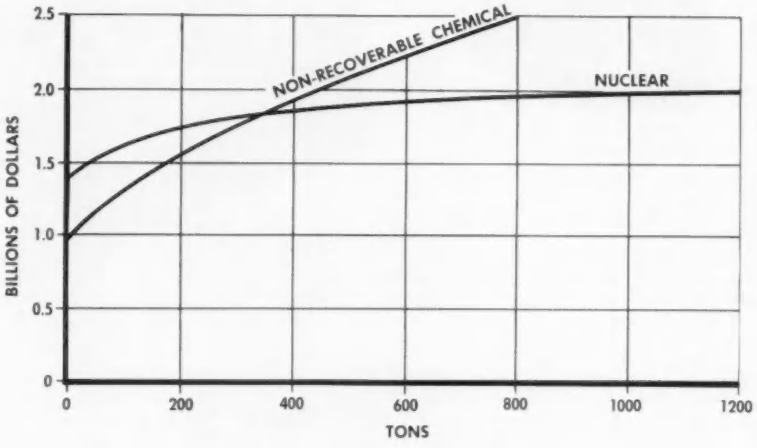


Fig. 4 — Superiority of recoverable nuclear rocket in payload delivery cost is indicated by this comparison with high-energy chemical system.

low for nuclear systems, but still high for the conventional chemical system.

Stocking the moon

Estimates have been made of direct operating costs, and launch and development costs. When these are combined into a total cost curve as a function of tonnage delivered, we get Fig. 4. This shows that even with high development costs assumed for the nuclear rocket (a debatable point), it requires the delivery of only some 400 tons of payload to the moon to make the curves cross. Estimates indicate it would take about 200 tons per year to keep a 20-man expedition supplied continuously on the moon. Thus, almost any operation other than the stunt of a single round trip for a few people would easily justify the development of the more economic transportation system.

To Order Paper No. 302H . . .
from which material for this article was drawn, see p. 6.

Meet Mobot . . .

the space service center

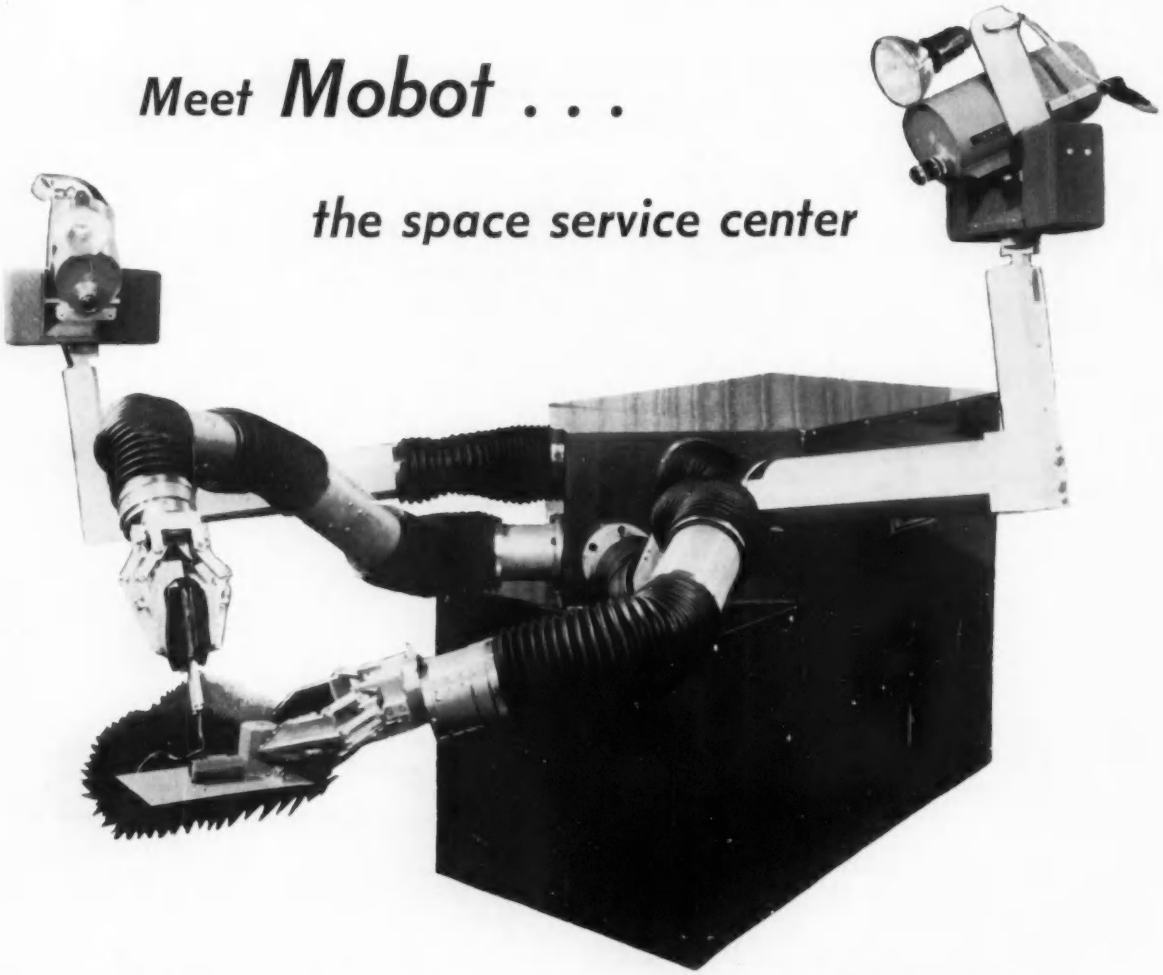


Fig. 1 — **Mark II Mobot,** originally developed for work in nuclear labs, may very well have future applications in space. It could, for example, allow a man seated in a safe space capsule to remotely assemble and repair orbiting space stations.

Based on paper by

John W. Clark

Hughes Aircraft Co.

THE hazardous regions of space force us to consider remote handling systems, such as the Mobot, for repairing, maintaining, and assembling equipment in orbit. Where the environment is so inhospitable that space suits, which place the man close to his work, are not feasible, and the manipulations so complex that a programmed machine could not do them, the Mobot can be used to advantage. It will be of real value when satellites become either too large to be orbited in one unit, or when their expense justifies maintenance rather than replacement. Fig. 1 shows the Mobot in action.

Originally designed for use in nuclear laboratories, the Hughes Mark II Mobot operates in areas too dangerous for an insufficiently protected man. It is equally adaptable to space. The brain behind the Mobot is supplied by the human operator. Safely situated in a protective capsule, he "sees," "hears," and "feels" what the Mobot is doing out in space. He tells it what to do next via a control console, similar to that shown in Fig. 2.

TV cameras at the work site lend the operator the all-important vision he needs to effectively control the Mobot. To add the feeling of "presence," an intercom system would let the operator hear the response of the moving parts of the Mobot. The sense of touch, particularly valuable where clear vision is blocked, can be supplied by pressure sensing devices. The form in which this data is presented to the operator can be by: indicating meters; audible tones; or numerical indicating devices.

Mobot in space

A typical future scene in space may very well resemble Fig. 3, where a Mobot vehicle is seen at work. The space Mobot will have many arms, giving it a

spider-like appearance. The two general-purpose handling arms shown in Fig. 1 will still be used, but additional arms are required to grasp the satellite being worked on and to carry the TV cameras. These arms would not have to be as complex as the handling arms. All the grasping arms would have to do is hold on to appropriate handholds on the satellite, or simpler yet, magnetic grips for attachment to ferromagnetic plates on the vehicle might be used. The camera bearing arms would be more articulate, allowing the operator to view the work from the best vantage point.

Auxiliary jets transfer the Mobot from its launch vehicle to the satellite upon which it is to work. The operator controls these jets remotely, to maneuver the Mobot to within arms reach of the hand grips on the satellite. This control is effected through the cable connecting the manned vehicle (control center) and the Mobot, which serves as the command and data link. Electric power for Mobot operation may also be supplied through the cable. If great separation exists between the operator and the Mobot, radio can be used instead for the communication link.

An example of how the Mobot would function in, say, an assembly type operation might be as follows. Assuming that two subassemblies have been orbited within a reasonable distance from one another, in approximately parallel orbits, the Mobot could join them. It would first attach a cable to one of these orbiting objects and then carry the free end of the cable to the other object. The Mobot equipment can then be used to draw the two objects together. After being brought into coincidence the Mobot would join them.

A major advantage of the Mobot is that it elimi-

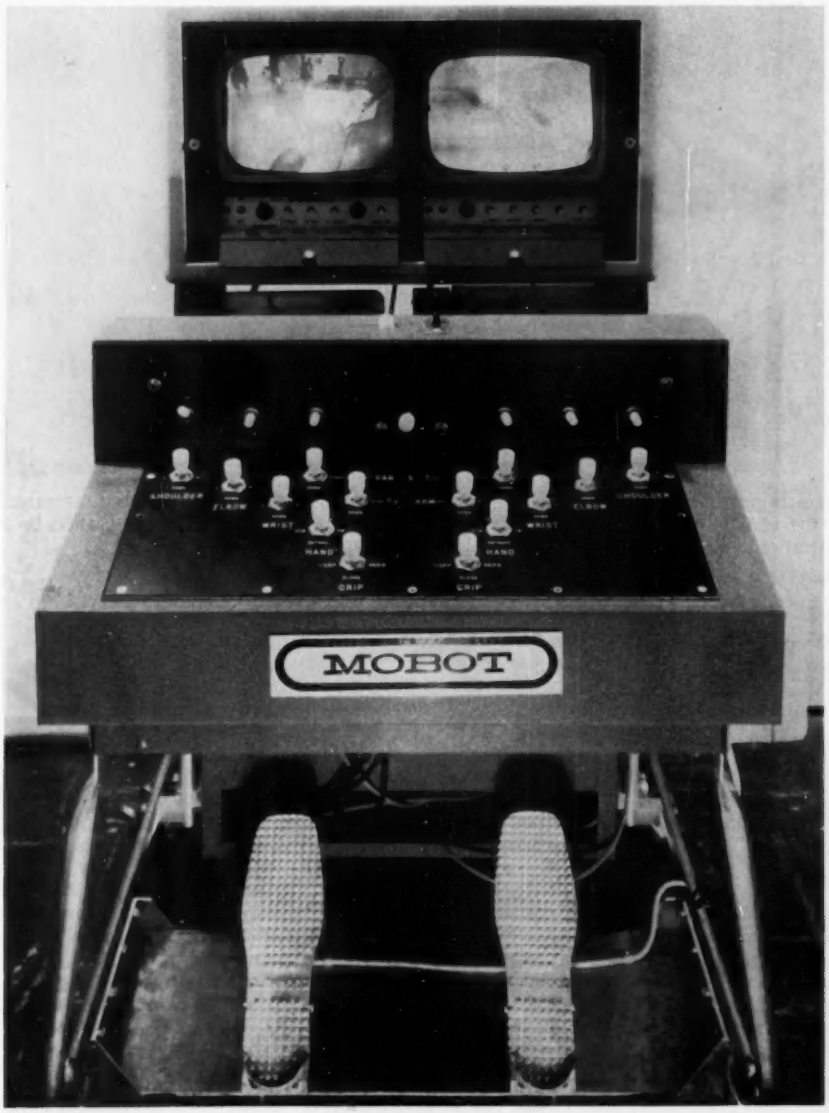


Fig. 2 — **Mobot control panel.** Here the operator communicates with his new "body." The toggle switches control the direction of motion of the arms and the vehicle, and the foot pedals control the speed of these motions.

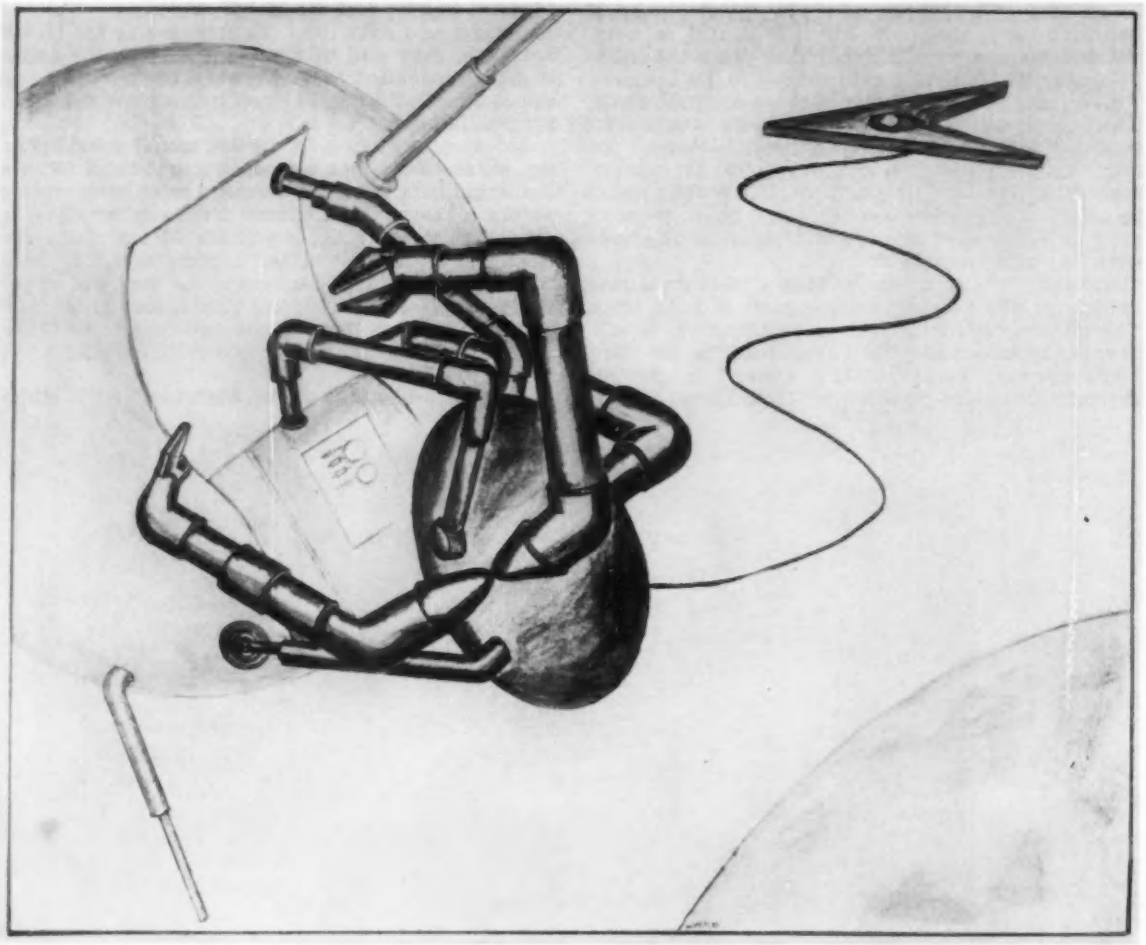


Fig. 3 — **The Spider-like Mobot vehicle needs many arms.** Some arms anchor it to its work, others carry and maneuver the TV cameras, and the rest do the work. In this sketch, the Mobot is shown connected to the control station by a cable which serves as the communication link. Radio could also be used for this purpose.

Mobot . . .
the space service center

. . . continued

nates the need of using space suits, thus minimizing total vehicle weight. The Mobot vehicle itself will weigh on the order of 200 lb; far less than any conceivable space suit. When the time comes that space stations are seriously considered, the Mobot could be used to assemble them, and subsequently service them, without the need for a space-suited astronaut. For repair work the operators would be housed inside the space station, safely and comfortably.

It becomes a new body

The experience gained on the Mark 11 Mobot indicates that man can very well get used to his new "body." After acquiring some skill in operation, many operators claim that they begin to "think like the machine." With this feeling of identity he becomes unaware of the mechanics of the control console and the use of these newly acquired muscles and senses becomes almost as natural as using his own body. This phenomenon is very fortunate since it will allow us to better separate the capabilities of the human brain from the limitations of the human body.

To Order Paper No. 344D . . .
from which material for this article was drawn, see p. 6.

Material drawn from an
SAE Metropolitan Section Paper

step by step . . . to the MOON

Confused about which space program is supposed to do what? Many of them are leading toward one eventual goal . . . sending a man to the moon. Here's a roundup of the numerous lunar projects, some still in planning, others ready to go.

Based on paper by

Col. Donald H. Heaton
NASA

MANY steps will pave the way for manned flight to the moon, which is itself an intermediate, but major step, towards manned planetary flight. The initial effort in this program is project Mercury . . . designed to loft a man into an earth orbit, and bring him back alive. Simultaneous development of unmanned lunar vehicles will allow tesfing of design approaches and subsystems such as terminal guidance systems, landing techniques, and landing gear designs which may later be incorporated in manned systems.

Missions for the unmanned lunar program include lunar orbiters, rough and soft landing packages, and mobile vehicles for remote exploration. The exploration of the lunar surface, its physical and chemical properties, will greatly aid in the planning and designing of manned instrument stations, and help solve problems of construction and life-support.

Of course the primary scientific objective in exploring the moon is for the information it can provide on the history of the solar system. The moon's surface, uneroded by winds or water, may carry a record of the early history of the solar system, now lost forever on earth, Mars, and Venus. The reason for sending a man there, is to gather this information. No amount of instrumentation will tell as much about the moon as man himself could tell, once he is there. Besides, only man can cope with the unexpected, which of course is the most interesting.

Can man take it?

How well will man perform in space? . . . . is the information we hope to learn from Project Mercury. This new environment may incapacitate man to such an extent that little advantage could be reaped from his presence in space. If this proves to be the case, now is the time to find it out. Subsequent space efforts may then be diverted along more promising lines.

The frontiers of flight will be vastly extended with the advent of Project Mercury. Flight speed will be increased by a factor of 8 over present achievement, altitude by a factor of 5, and the environment encountered has not yet even been approached. The many technical advancements, required by this ex-

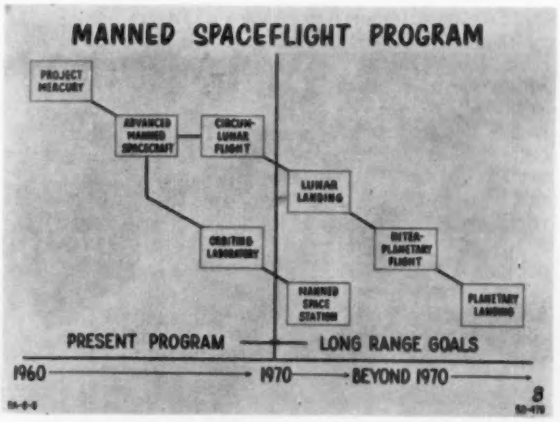


Fig. 1 — Manned spaceflight program. Assuming that Project Mercury confirms the expectation that man will indeed be useful in space, these projects will deliver a man to the moon. Also planned is a manned space station.

Eventually, it is hoped, that the planets will be included in our range of travel.

tension of the flight envelope, opens the door to the next step in manned space flight.

Project Apollo will mature next. Spacecraft will be designed for manned circumlunar flight and will allow man to perform useful functions. It should also be capable of being used as an earth orbiting laboratory, a necessary step toward the establishment of a permanent manned space station. In the long run, this spacecraft should lead towards manned landings on the moon and planets.

Landing this spacecraft on the moon with presently planned booster capability, namely the Saturn C-2 vehicle, requires the use of orbital assembly and refueling techniques. A much larger vehicle than the Saturn will be required to confer escape velocity, without orbital staging, to an Apollo spacecraft fitted out to land on the moon and return to earth. For the landing, a considerable amount of trajectory control will be needed, placing severe requirements on the navigation and control system.

A summary of the steps involved in the manned spaceflight program, along with the expected dates of completion, is presented in Fig. 1.

Modular design considered

Before circumlunar missions are attempted, earth orbital flights will be required for vehicle evaluation, crew training, and for the development of operational techniques. To achieve this multiplicity of missions a "modular" design may be desirable.

The spacecraft would consist of three basic modules: a command center, a propulsion module, and a mission module. A fourth module may be required for the additional velocity increment required for lunar landing.

The command center would house the crew during the launch and reentry phases of flight. During the remainder of the mission it would serve as a flight control center. This module is the only one with reentry and recovery capability.

The propulsion module can, in a sense, be likened to the escape tower and retrorockets on the Mercury capsule. Its primary function is to provide a safe return to earth in case of an aborted mission. It might also be used to make midcourse corrections for a circumlunar flight, or to place the vehicle into a lunar orbit and subsequently eject it from the orbit.

The mission module would be used to provide better living quarters than the command center can afford, for lunar flights. It could also carry scientific equipment.

Unmanned spaceflight program

The groundwork for manned landings on the moon will, as already noted, be prepared by an intensive unmanned lunar program. As a first step, the Atlas Able 5 lunar orbitor will be launched in an effort to better understand the lunar environment. Instruments to detect energetic particles and measure magnetic fields, will be aboard, to see if trapped radiation belts exist. Scientists are particularly interested in particle streams from the sun which are known to, on occasion, last long enough to kill a man. With the information gathered, it is hoped that solutions to the shielding problem (how much, what kind, and placement) will be forthcoming. Of course when man finally does land on the moon the question arises; will he have to stay near the landing craft, which is shielded, or will flare predictions be available so that he may safely venture away?

Valuable experience with midcourse and terminal control of the Able 5 and succeeding vehicles will also be obtained.

The Ranger program to bring an instrument capsule to a rough but safe landing on the moon, will be underway by the time results from the Able 5 environmental studies are obtained. More sophisticated experiments will be conducted, including vidicon camera and television systems, gamma ray spectrometers, and seismograph systems. This vehicle will be launched by the Atlas Agena B. This vehicle is capable of upper stage restart and coasting flight attitude control. This permits the Ranger to be coasted in a parking orbit where a second interval of rocket operation will put it on its ascent trajectory to the moon. Launching opportunities per year are increased by this capability.

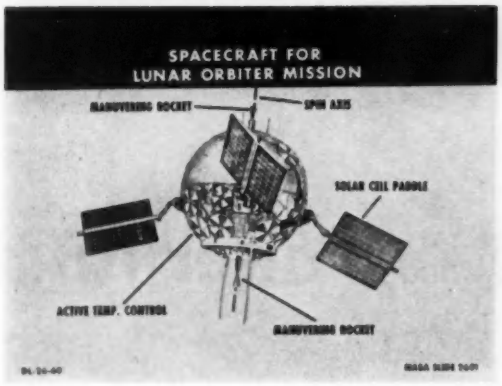
These two spacecraft are well along in development, and so are their scientific payloads. More advanced missions will be performed by the Surveyor and Prospector spacecraft, now in the planning stage. Fig. 2 shows the various spacecraft which will lead up to manned lunar flight.

The Surveyor will be launched by a Centaur vehicle, and will be capable of soft-landing a 100–300 lb scientific payload on the moon. The instruments will be capable of making our first direct measurements of the physical and chemical properties of the lunar crustal material. Measurements to a few feet below the surface will be made by drilling. The array of instruments will include gas chromatographic analyzers for detecting the presence of organic molecules. Panoramic and close-up photographs of the moonscape surrounding the capsule will be made with vidicon cameras and a selection of lenses.

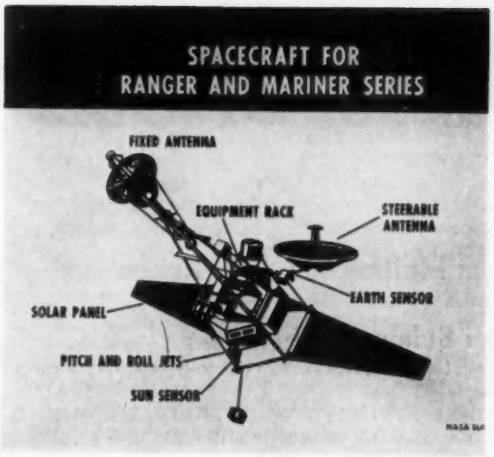
To extend our knowledge over the whole moon, the data from the few sample locations will be compared to data from a precision lunar orbiter. From a distance of a few hundred kilometers above the surface, this orbiter will conduct a geophysical and geochemical survey of the whole moon. Correlation of these data will afford a better understanding of the vast stretches of moon untouched by the sampling capsules.

The Prospector program, currently under study, involves soft landing a "truck" plus several alternate payloads. The launch vehicle would be the Saturn. Terrain permitting, this mobile laboratory would explore throughout a radius of perhaps 50 mi, obtaining far more data than a stationary payload. The areas of particular interest, highlighted by previous flights, could be more thoroughly investigated.

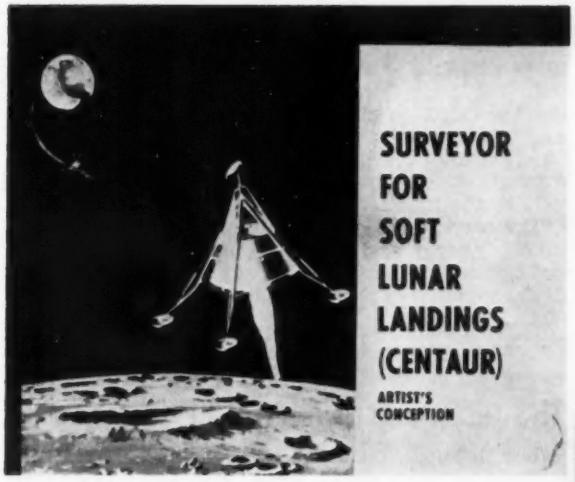
To Order Paper No. S276 . . .
from which material for this article was drawn, see p. 6.



a — Rough lunar orbiter to gather preliminary information.



b — Ranger spacecraft will deposit an instrument bearing capsule on the moon.



c — Surveyor will make soft lunar landings and will send back panoramic and close-up photographs of its lunar surroundings. A drill will extend investigation of lunar crustal material to several feet.

d — The prospector would be capable of soft-landing a "truck" on the moon. (Other payloads are also envisaged.) About 50 mi radius could be investigated this way.

Fig. 2 — Unmanned spaceflight program. These vehicles will provide the necessary information for designing a safe spacecraft for manned lunar flight, and in themselves represent significant exploratory effort.

Though presently in its infancy . . .

MHD may Push and Power future

Based on papers by

William McIlroy and A. E. Kunen
Republic Aviation Corp.

and Ali Bulent Cambel
Gas Dynamics Laboratory, Northwestern University

MHD (magnetohydrodynamics) may well be a future source of space propulsion and electrical power. As a thrust system, it has received much attention along with two other electrical propulsion systems. The others are the ion engine and the electrothermal jet.

MHD applied to power generation offers a feature ideal for space flight; no moving parts are involved. This precludes the requirement for perfect balancing, which would otherwise be needed to prevent disturbing torques being applied to the vehicle. Low gravity lubrication problems are also eliminated. The MHD generating system can also be employed for ground plants.

Space propulsion

Simply stated, MHD comes about when an electromagnetic field interacts with the field of an electrically conducting fluid such as mercury or an ionized gas. Propulsion is derived from this principle, through the acceleration of plasmas or ion streams.

All plasma accelerators use the basic driving mechanism of Lorentz force generated by a magnetic field coupled to an electric field, somewhat equivalent to an electric motor. The accelerator can either be a pulsed or a continous flow device. The pulsed accelerator produces the force by applying a time varying electric (E) field which induces its own magnetic (B) field, or alternatively, by applying a time varying B field to induce its own E field. The continuous accelerator, which will not be discussed further, generates the force by applying both the E and the B field externally.

Producing the plasma

Plasma is produced by an electrical discharge which may be either direct or indirect. A direct discharge occurs when a voltage is applied to a gas whose pressure is sufficient for breakdown. A current begins to flow and the gas is partially converted into a plasma. The current is oscillatory due to the nature of the circuity. This high intensity current, in turn, induces strong magnetic fields, which, coupled with the current, provide the driving force.

An indirect discharge again produces an oscillating discharge in the plasma. Here, energy is discharged through a metallic conductor and not through the gas. The strong, time-varying, magnetic fields associated with the varying current in the conductor, flux the gas in the accelerator tube. Eddy currents are induced in the gas and interact with the generating magnetic field to produce the driving force. A large part of the gas is accelerated not in the axial direction, but in toward the axis, where a high temperature, high pressure plasma is formed. Subsequent expansion in the axial direction acts in the manner of an electrothermal jet.

The work done on the plasma is converted into kinetic energy and internal energy of the gas. To get the most kinetic energy out of the system, it is desirable to have the internal energy as low as possible. This also increases the device's specific impulse.

The "magnetic piston"

The physical nature of the discharge is best described as being either a line or a sheet discharge. A line discharge refers to a high intensity current flowing in a thin tube; confined there by the strong induced magnetic fields which encircle it. A sheet discharge is a current distributed over a thin sheet. They are generally axisymmetric and closed on themselves.

The sheet discharge is preferred, since pressure is created over an area approximately normal to the desired acceleration direction. Line discharges accelerate the plasma in all directions and are thus not very efficient. Besides, concentrated line discharges cause electrode erosion which consequently shortens electrode life.

The sheet, often called the "magnetic piston," drives the gas ahead of it as it moved along by the Lorentz force. The gas is admitted through a small orifice at the closed end; the discharge takes place before or very slightly after the gas front reaches the exit.

space ships

MHD generation

In the MHD generator the plasma moves through an externally applied transverse magnetic field. The plasma is decelerated here and an electric field is generated normal to both the magnetic field and the flow direction. If an external load is applied, a current will flow and power will be generated.

Two factors greatly influence the generation of electricity: material problems and magnetic field strength. The material problems arise from attempts to increase the gas conductivity. High gas conductivity, a prerequisite for successful operation, is achieved through the use of either a very high temperature or a reasonably high temperature accompanied by seeding of the gas. The material problems introduced by the high temperatures and the use of seeding material are deciding factors in the practical application of such a device.

The attainable power density increases sharply as the entrance stagnation temperature of the gas is increased. Consequently, the large increase in performance possible for small increases operating temperatures, provides a strong incentive for design sophistication and even a small increase in material capability.

Magnetic field strength, it would appear, determines the size of the current that can be generated. However, the magnetic field tends to reduce the conductivity in the direction of the field. A serious reduction in the attainable power results.

For space applications, since relatively low power is required, a permanent magnet may be adequate to supply the field. Some of the novel applications envisaged are to use the hot exhaust jet of a rocket, or possibly the ionized flow field around the blunt nose cone of a hypersonic vehicle, as the working plasma.

For ground plants where large powers are desirable, the cross-sectional flow area will have to be large, necessitating the use of electromagnets where energy losses can be considerable. It is also desirable, in ground applications, to preserve the seeding material. This can be done by operating in a closed cycle, or if an open cycle is used it can be condensed out.

To Order Papers No. 312A and 312B . . .
from which material for this article was drawn, see p. 6.

HIGHLY indicative of the state of the art of magnetohydrodynamics is the statement that it constitutes the "happy hunting grounds" for the scientist and engineer. A respectable body of analytical studies of plasma properties exists; however, experimental work and applications are still in their infancy.

Presently, data concerning plasma properties are scarce. The difficulty arises in the design of measuring devices to withstand the high temperatures involved in plasma phenomenon. Even if measurements were readily made, their validity would be questionable, due to the doubtful existence of equilibrium in many plasma and magneto-gas dynamics flows. In addition, identification of different causes is difficult because of the coupling of the various phenomenon. The problem of measurement is also hampered by the lack of reliable diagnostic equipment working in the microsecond range.

The flow disturbances produced by the direct introduction of probes into a flow system, make indirect measurement a technique likely to be required. For this reason, many of the measurements rely on the numerous forms of optical spectroscopy, microwave transmission and attenuation techniques, and optical flow visualization based on measurement of the refractive index. However, the use of Langmuir probes and ballistic pendula have considerable promise.

Two basic classes of apparatus are used for the study of magneto-gas dynamics applications; the electromagnetic shock tube and the plasma hyperthermal wind tunnel. The shock tube, which accelerates the gas by the interaction of currents and their magnetic fields, can achieve very high Mach numbers and enthalpies. This apparatus is useful in plasma diagnostics, plasma dynamics, hypervelocity aerodynamics, and magneto-aerodynamics as well as thermonuclear reaction.

The hyperthermal wind tunnel, unlike the shock tube, has continuous flow operation. It may be used effectively in materials testing, MHD power generation, as well as electro-thermal and electromagnetic propulsion.

What Makes Engines Rumble?

Based on paper by

V. F. MASSA

Esso Research & Engineering Co.

DISTORTIONS of combustion process timing result in abnormal combustion — including surface ignition and rumble — in spark-ignition engines. When such distortions cause maximum combustion pressures to occur at or near tdc, the pressures and rates of pressure rise developed are abnormally high. The result is vibration of the crankshaft in the 600-1200-cps frequency range, which is heard as "rumble."

Abnormally early peak-pressure development, usually accompanied by rumble, may be caused by one or more of the following:

- Ignition of the fuel-air mixture prior to (but not excluding after) spark ignition by the presence of leaded carbonaceous deposits, either accumulated or aspirated.
- Early ignition caused by abnormally advanced ignition timing.
- An increase in the mass rate of burning of the charge.

The last factor — mass burning rate — may be increased by the following:

- Fuels such as benzene, with inherently high rates of burning.
- Combined thermal, catalytic, and volumetric effects of accumulated deposits in the combustion chamber.
- Aspirated deposits, aside from their tendency to ignite the fuel-air mixture earlier.
- Variation of fuel-air ratio, combustion chamber temperature, or other unknown factors that may differ among different cylinders of a multicylinder engine.

Mass burning rate is important with respect to rumble. Accumulated combustion chamber deposits reduce the fuel mass burning times by 10–14%. For this reason, it is necessary that this influence be separated from that of deposit ignition, when studying abnormal combustion phenomena that may lead to rumble.

LIB reference fuels have been widely used for the measurement of rumble throughout the automotive and petroleum industries. (O-LIB is benzene plus 3 cc tel; 100-LIB is isooctane plus 3 cc tel)

The data indicate that the average mass burning rate of O-LIB was 10–14% faster than that of 100-LIB. This infers that, for comparable engine cycles, O-LIB will always cause earlier peak cylinder pressure development than 100-LIB.

For this reason, it is desirable to exclude those effects that may be caused by mass burning rate differences between LIB fuels when they are used to measure the rumble and surface ignition behavior of other fuels. This is especially so, since it is possible to have rumble intensity differences primarily caused by differences in the mass burning rates of the LIB fuels, without the presence of deposit ignition.

This type of rumble may be eliminated by a reasonable retardation of ignition timing. This suggests that fuel surface ignition behavior may be better evaluated at ignition settings that do not reflect rumble differences in terms of the mass burning rates of the fuels used. Depending on deposit levels present, and after correction for differences in mass burning rate, O-LIB fuel showed 8–18% surface ignition, compared to 1–5% for 100-LIB.

It has been found that rumble caused by high mass fuel burning rates cannot be reduced by phosphorus-type additives. When used at a concentration level of 0.2 theory, however, this type of additive was effective in reducing rumble due to deposit ignition, at 10/1 compression ratio. At 12/1 ratio, it appears that at least 0.5 theory of such an additive would be necessary to achieve the same effect.

Differences in surface ignition behavior between fuels of the LIB series were minimized in the presence of aspirated deposits compared to differences found in the presence of accumulated deposits. It is possible that the deposit aspiration levels used were high enough to "saturate" the combustion chamber. For this reason, the deposit aspiration techniques used were not acceptable substitutes for the normally used deposit accumulation tests. Differences in "flame speed" noted between different LIB fuels during normal combustion were also reflected, to some extent, during deposit aspiration.

Instrumentation

The above conclusions are based on a study of fuel performance in relation to abnormal combustion phenomena accomplished by observation of the distribution of flame arrivals at ion gaps located within the engine cylinders, or peak pressure position in terms of crank-angle degrees. The instrumentation used is shown schematically in Fig. 1.

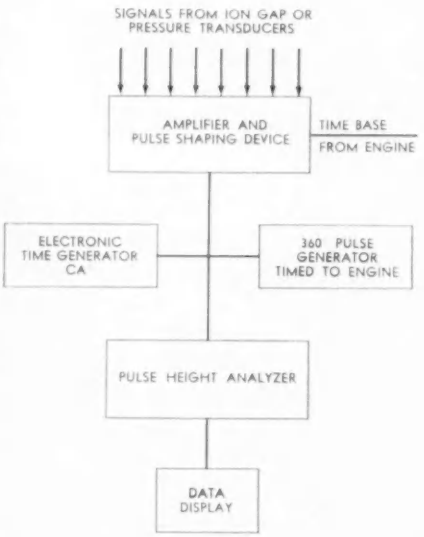

SIGNALS FROM ION GAP OR PRESSURE TRANSDUCERS
AMPLIFIER AND PULSE SHAPING DEVICE
TIME BASE FROM ENGINE
ELECTRONIC TIME GENERATOR CA
360 PULSE GENERATOR TIMED TO ENGINE
PULSE HEIGHT ANALYZER
DATA DISPLAY

Fig. 1 — INSTRUMENTATION used to obtain distribution diagrams of flame arrival at ion gaps, or time of peak pressure occurrence.

Signals from either ion gaps or pressure transducers are amplified and suitably shaped. This information is fed to pulse height analyzer, which counts number of ion gap flame arrivals or pressure peak occurrences on time basis.

360-deg pulse generator attached to engine furnishes time base to electronic time generator that in turn provides this information in terms of crank-angle degrees to height analyzer.

By superimposing crank-angle degrees upon data furnished by either ion gaps or pressure transducers, it is possible to develop distribution diagram of type described in complete paper. Series of metal pins inserted in flywheel at suitable crank-angle degrees are also used in conjunction with magnetic pickups. This information may also be used, with instrumentation described, to check crank positions indicated electronically.

The above conclusions are based on a study of fuel performance in relation to abnormal combustion phenomena accomplished by observation of the distribution of flame arrivals at ion gaps located within the engine cylinders, or peak pressure position in terms of crank-angle degrees. The instrumentation used is shown schematically in Fig. 1.

■ **To Order Paper No. 293C . . .** from which material for this article was drawn, see p. 6.

Many Liquid Metal Properties Estimable

Based on paper by

B. F. BROWN and S. W. STRAUSS
U. S. Naval Research Laboratory

MUCH progress has been made in liquid metal processes during the relatively few years of interest in this technology.

Several properties of liquid metals of importance to the design of heat transfer systems can now be estimated from basic properties of the elements. These estimable properties include viscosity, surface tension, thermal conductivity, and specific heat.

The largest uncertainty in these physical properties is the effect of temperature, for which the principles determining the coefficients are not yet well developed.

The status of principles for container alloys is not really such that one should use the term "designing" when referring to specifying or developing materials to contain liquid metals. But, even so, sufficient guidelines have emerged to enable the search for such materials to be made efficiently. Also, the problem of developing an alloy to resist attack from the liquid metal side of a heat exchanger is now not nearly as formidable as heretofore. More difficult is modifying the alloy to make it resistant — if it is not initially so — to high-temperature attack by air or steam . . . if these are the fluids on the other side of the heat exchanger.

■ **To Order Paper No. 280D . . .**
from which material for this article was drawn, see p. 6.

Balloon to Slow Re-entry Vehicles

Based on paper by

F. R. NEBIKER
Goodyear Aircraft Corp.

AN inflatable balloon-type system for space vehicle recovery has been shown feasible, where conventional parachutes are unable to aid effectively. Such a device offers positive stabilization and deceleration, for recovery from high-speed, high-altitude flights regimes, where parachutes become useless. This efficient drag producing device, stable over the Mach 3 speed range, has many far reaching applications. These include recovery of a man or man-seat combination, manned escape capsules, nose capsules, nose cones, and other hypersonic re-entry devices. As a specific example, a Mercury type capsule rigged with a 21.6 ft diameter balloon could achieve positive re-entry into the atmosphere within one revolution. Tumbling re-entry bodies requiring alignment to a particular flight path angle for effective use of heat shielding, can be stabilized with the balloon. Also considered, is the use of such a high-speed drag device for superobrital re-entry conditions, thereby reducing orientation mechanisms and retrorocket requirements for initial deceleration.

Prototype balloons have been developed using a lightweight Dacron-neoprene material. The balloon is packaged and stored in a small lightweight container. Fiberglass pressure bottles, capable of storing compressed gas to 5000 psi, serve to inflate the balloon. A squib-operated frangible valve, when actuated, ports the gas through a manifold of inflation tubes designed to control local pressures during the initial surge. Under dynamic conditions, the balloon can be inflated in under 1/10 sec.

The design of the balloon itself employs a series of meridian hoop cables around the balloon, terminating in a single riser line on the nose. This method of support places the balloon fabric under inflation loads only and avoids any single point tearing stresses. To achieve positive flow separation and stability at subsonic speeds, a vortex generator or burble fence is used.

The balloon is deployed behind the primary body with a reel designed to operate smoothly and evenly under various loading conditions. To give a maximum coefficient of drag, 3 balloon diameters separate the balloon from the primary body.

■ **To Order Paper No. 344C . . .**
from which material for this article was drawn, see p. 6.

When Is Cold Starting Easy in Diesel Engines

Based on paper by

W. E. MEYER and J. J. DE CAROLIS
Pennsylvania State University

STARTABILITY of compression-ignition engines, and particularly the first ignition, depends primarily on the temperature conditions in the combustion chamber and the ignition characteristics of the fuel. The latter cannot be defined in simple terms. In an engine the temperature needed to produce ignition varies with conditions such as the fuel-air ratio; the time available for evaporation, mixing, and preflame reactions; the pressure; the configuration of the combustion chamber; the air motion in the chamber; and the purity of the mixture. Starting with ether vapor eliminates several of the variables that exist when fuel is introduced into the cylinders in liquid form. The vapor-air ratio and the time available for preflame reactions become the dominant variables.

A definite relationship exists between the fuel-air ratio and the self-ignition temperature of a homogeneous fuel-air mixture. This is shown in a general way in Fig. 1. If the mixture is too lean or too rich at a given temperature, ignition will not take place. As the temperature is decreased, the minimum fuel-air ratio required for ignition increases until a minimum temperature is reached below which ignition will not take place, no matter what the fuel-air ratio is. As this temperature is approached, the range of the fuel-air ratios for ignition narrows until at the minimum temperature, only one definite ratio will support ignition. This is one reason why it is so difficult to obtain successful engine starts under marginal conditions.

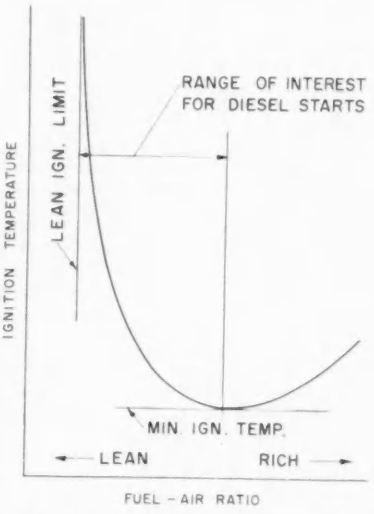


Fig. 1 — General relationship between temperature required for spontaneous ignition and ratio of fuel and air in a homogeneous mixture.

■ **To Order Paper No. 272A . . .**
from which material for this article was drawn, see p. 6.

Specific cases show how line production men and "specialists" must find ways to blend their decision-making talents to insure . . .

Built-in as well as Designed-in

RELIABILITY

Based on paper by

H. P. KEAN
Wright Aero Division, Curtiss-Wright Corp.

THE RELATIVE DEGREE of responsibility taken by the line production man and the production specialist affects measurably the "built-in" reliability of a product which manufacturing must contribute. The increasing existence of specialists in modern manufacturing tends to dampen the line production man's responsibility toward product reliability. Refinement of the production engineer's sphere of activity — and emphasis on schedule by line manufacturing personnel — has narrowed the scope of product reliability for the line production men.

The line supervisor has begun to accept the specialist, to be sure, but divergence in their attitudes toward reliability is evidenced in their different modes of operation.

The specialist tends to use scientific techniques almost entirely — neglecting some of the non-scientific circumstances which are always present. The line supervisor, on the other hand, is relinguishing more and more responsibility for investigative and corrective work, because he feels this to be under the specialist's jurisdiction. He confines himself to managing people, costs and schedules . . . neglects the scientific tools available for trouble-shooting and decision-making.

In general, these tendencies are natural and proper. But specific situations are not "in general." A great difference in results will lie in the degree to which the specialist ignores the need for intuition and experience; the degree to which the line supervisor fails to take advantage of available scientific tools.

"Cost Down; Trouble Up"

Take a recent incident, for instance, in which cost reduction was being sought in production of a thrust washer.

The washer had always been produced by machining the oil reliefs in both faces and then grinding the residual area flat. A certain amount of out-of-flatness was tolerated because the piece was somewhat flexible.

The process engineer was asked to find a way to produce the washer more cheaply — preferably by stamping. He found it difficult to demonstrate dies which could successfully hold close tolerances. But he worked on the problem and finally announced: "Here is an acceptable solution."

At this point, each specialist proceeded to do his job as he saw it. Inspection reported that the parts were to blueprint. Manufacturing Engineering approved the machine as capable. To all outward appearances, the job had been well done.

BUT, the stamping produced a series of slight high points directly opposite the oil reliefs.

These high points were within blueprint specifications, but represented a type of out-of-flatness considerably different than that previously experienced by the slight warping after grinding. These high spots caused excessive wear on the mating part . . . and produced active customer dissatisfaction.

In retrospect, of course, the question was asked: "How could this have been prevented?" The answer never did become clearcut. Each person involved had performed his particular function. . . . But **if just one of the group had felt responsible for product reliability in a general sense,** he would have requested a performance test. Thus the problem would have been prevented from arising in the delivered product.

Blended Talents Win

Another recent instance — with a happier ending — is a case where the foresight of a stress engineer avoided the dangers inherent in using the results of scientific analysis without careful checking of the validity of the data source . . . or in accepting intuition without reasonable evidence.

In this case, a mismatch in the girth weld between two cylinders of a missile case was calculated by the stress engineer to determine its effective strength. Direct measurements produced a calculated answer which showed that the case had absolutely no chance of passing the pressure test.

To stop production at that point meant serious jeopardy of the delivery schedule, as this was a special unit. There appeared to be no choice other than to start time-consuming rework.

But the stress engineer — before releasing his final recommendation — consulted a welding technician to see if there were any extenuating circumstances which were not readily apparent. The welding technician told him: "In my experience, this kind of a mismatch is not always caused by pure radial slippage. Sometimes it is caused by a type of warpage which does not seriously decrease overall strength."

So, with the odds against failure greatly reduced, it was decided to finish the case and to test it under instrumentation.

This was done . . . and the test was successful.

This is one of many illustrations which might be cited to prove the need for a blending of decision-making techniques among production people.

■ **To Order Paper No. 336 A . . .** from which material for this article was drawn, see p. 6.

Special Hazards Block Flight to Moon

Based on paper by

R. O. LOWREY and J. T. RAY
Lockheed Aircraft Corp.

FROM what we know now, radiation, meteoroids, and emergency escape are among the major obstacles to lunar flight. A lot of work will have to be done to overcome these if the target date of 1970 is to hold.

There are two types of radiation — cosmic and trapped or "Van Allen Belt." Cosmic radiation is not too serious provided flight does not take place during large solar flares which occur about twice a year. There are two belts of trapped radiation. The maximum intensity of the inner belt is placed at 2400 miles above sea level. The radiation consists of both electrons and protons and enough is known about them to permit reasonably accurate calculations for shielding. The maximum intensity of the outer belt is at 10,000 miles above sea level and

it increases during periods of solar activity.

Meeting the Radiation Hazard

To deal with radiation you can vary two factors — the vehicle path and velocity, and the crew shield. Two trajectories are possible, each of which is a transfer ellipse. One is within the earth-moon plane (coplanar) and the other is a polar trajectory.

The coplanar orbit passes through the heart of the trapped radiation belts. The total integrated dose for a one-way flight is 20.2 rem, which is unacceptable by known standards except in real emergencies. If a solar flare should occur after departure from earth, the dose would be greatly increased.

The polar orbit avoids the trapped radiation belts, but the hazard of solar flares remains. This orbit has its drawbacks. It would require an added velocity of 1200–1400 fps to offset the loss of the earth's rotational component, and the guidance problem is more difficult because of reduction in the apparent size of the target.

Methods of Shielding

One could use special shielding material or the stored rocket fuel to shield the crew from radiation. Two types of shield are considred, both employ steel and polyethylene. One would cover the entire compartment area; the other just a special compartment to be occupied while passing through the radiation belts. Frequency of trips would decide the "best" shield.

Use of rocket fuel for shielding might give some relief from the weight penalty of special shielding. There would be plenty of fuel on the outbound trip, but not enough on the return. The crew would have to hunt around for a substitute material on the moon, presumably powder or dust, and fill the emptied fuel tanks with it.

Meteoroids come in assorted sizes. There are dust balls — very loosely bound particles — and solid stuff which ranges in size from the microscopic to boulders. The seriousness of penetration of the pressure cell depends upon hole size and resultant loss of cabin gaseous environment.

Suggested means for coping with this problem are: the "whipple bumper," self-sealing skins, thicker skins, and the pressure suit. A skin thickness in excess of that needed for internal cabin pressure coupled with a pressure suit looks like the best solution. But a space suit is an awkward garb for walking around on the surface of the moon. Here you would want a thin, flexible material for at least parts of the suit to give free body movement. Moreover, resealing the suit once punctured will be difficult because the hole will be accessible only on the low pressure side.

Components will fail on round trips to the moon and the crew must be salvaged for reasons other than the pure humanitarian:

- The crew may have found out something which can prevent similar failure in the future.
- Crews cost money to train.
- Safety will avoid the necessity of paying crews large monetary inducements.

In the interest of safety you have to provide a means of getting away from the source of danger, transit to a safe place, and life support during transit time. A five-stage lunar vehicle and a lunar-based rescue vehicle would seem to be the best system, but emergency escape still calls for a lot of research. In fact, of all the hazards to be overcome it is farthest from solution.

■ **To Order Paper No. 302C . . .** from which material for this article was drawn, see p. 6.

Design Changes Can Help Control Heat-Treat Distortion

Based on paper by

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Wright Aeronautical Division, Curtiss-Wright Corp.

NON-UNIFORM response to heat-treatment — one of the prime causes fo distortion — can frequently be traced to differences in section thicknesses throughout the part or in unsymmetrical configurations.

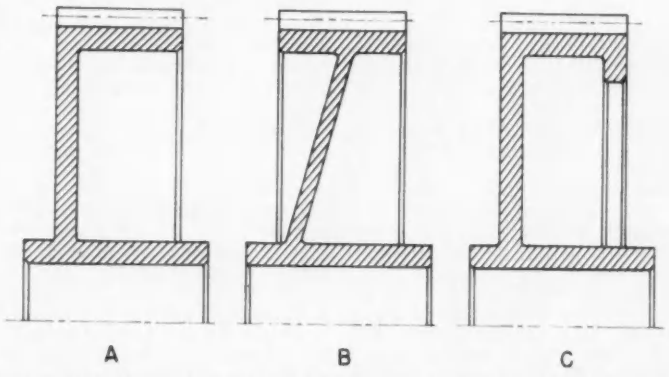
Both of these conditions can be controlled to some degree during the design of the part. Sketch A of the illustration shows that the original design of a certain gear was not only unsymmetrical, in that the rim of the gear was supported by the web at only one end, but the relatively thin web contributed little support to the rim to resist deformation during heat-treatment. The stresses imposed upon the gear during heat-treatment were sufficient to cause this unsupported end of the rim to distort beyond drawing limits.

The design change shown in sketch B moved the supporting web of the gear to the center of the rim, thereby providing uniform support for the rim and eliminating most of the distortion.

An alternate method of achieving the same end is shown in sketch C. In this case, a web has been added to the unsupported end of the rim to provide additional strength, thereby minimizing deflection during heat-treatment as well as during operation.

It is this area of design that offers the most direct and most effective means of preventing distortion and should be the area where initial efforts should be directed.

■ **To Order Paper No. 340C . . .** from which material for this article was drawn, see p. 6.



How distortion was controlled in a gear: A — original design was subjected to stresses during heat-treatment that were sufficient to cause unsupported end of rim to distort beyond drawing limits; B — this design change eliminated most of distortion; C — alternate method of achieving same end.

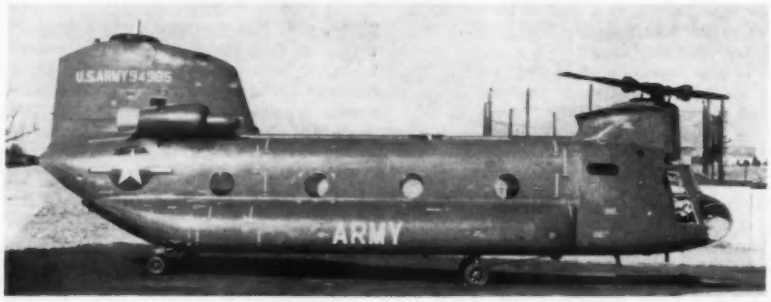


Fig. 1 — The Chinook, under development for the Army, is a medium-transport helicopter, powered by twin 2200-hp gas turbines, and capable of carrying a 3-ton payload or 32 combat-equipped men.

Army Pushing Gas Turbine Development

Based on paper by

LT.-GEN. ARTHUR G. TRUDEAU

Chief of Research & Development,
Department of the Army

THE gas turbine appeals to the Army because of its light weight, ease of maintenance, and reliability under cold-start conditions. Its development is being encouraged in four major areas — to serve as a power-boost unit, a cold-starting aid, a main powerplant, and in small units ranging from 0.5 to 20 hp.

A simple, nonregenerative turbine, to boost the power of the main source when peak output is needed, would be a great aid to the military on the battlefield. So also would be a cold-starting unit. Studies are being conducted with a variation of the Solar Titan 65-hp turbine to blow heated air over the main engine compartment and provide electrical power to energize the starter. Small, reliable turbines should also start readily in extreme cold.

Mobility via the Air

To achieve greater mobility for its ground forces the Army looks to the air. It wants vehicles that will fly just above the nap of the earth, combining take-off and landing characteristics of the helicopter with the advantages of the fixed-wing aircraft. And the turbine promises to provide the means to get them. Several types of aircraft are under development and one of them, the Chinook, should be in use in a few years (Fig. 1).

The use of the turbine to power all types of ground vehicles is not being overlooked. The Army and Navy have a joint program for developing a 600-hp turbine. The Army wants it for a main battle tank and expects it to compete favorably with existing tank diesels in size, weight, and fuel economy.

Lighter and more efficient transmissions are needed if the gas turbine is to meet requirements and that is spurring integration of the power source and transmission in a single unit. In this regard, two approaches are worthy of attention — high-pressure hydraulics, and electric drive. Both indicate a high potential and the Army is studing them with great interest.

■ **To Order Paper No. 297A . . .**
from which material for this article was drawn, see p. 6.

Autoflare landings In zero-zero conditions

Based on paper by

R. K. SMYTH and E. W. VELANDER

Autonetics

THE AUTOFLARE system, designed to provide flight operation when weather conditions are less than normal ILS minimums, has been tested successfully and showed good prospects for future use. By extending the terminal guidance control to touchdown and roll-out on the runway, landing in zero-zero conditions would be feasible. At existing minimum instrument conditions additional safety is provided.

The information provided by the autoflare system can be used in two ways. Coupled with an automatic flight control system, it provides fully automatic touchdown and ground roll-out. Alternately, the Autoflare system allows the pilot to perform a manual instrument landing by referring to the displays, which receive information from the Autoflare computer.

Although the first mode of operation puts the pilot in the role of supervisor, monitoring system operation, he can make small corrections to the system or take over and initiate a go-around. The small discretionary corrections are introduced to the system by an input force transducer located on the pilot's control column. In the second mode of operation the pilot assumes an active role in controlling the vehicle, making for flexible operation. Cockpit procedures will be the same as those in effect during the standard ILS approaches. During manual instrument approaches the same piloting techniques are used when the Autoflare system extends the ILS approach to touchdown.

Fail-safety is provided in the form of backup systems of degraded performance, rather than duplicating or triplicating the complete landing system. This approach saves weight and cost, yet provides "fly-to" information which allows the pilot to make precise and stable control during the flare trajectory. Backup information of a more primitive form is also provided, to allow the pilot to decide on a go-around or to make a rough but safe landing using the unaugmented information. This raw information includes the terrain clearance altitude and sinking rate, and a simple weighted combination of altitude and altitude rate fed to the "bug" on the altitude display indicator.

A press-to-test button is provided to check the equipment operation before starting the approach. Self-test circuitry is included in the Autoflare to provide a failure indication during the approach and landing.

To assure fail "soft" action, maneuver limiting is provided in the event that a hardover failure of the flare computer occurs. The maneuver limits are satisfactory to prevent a sudden change in altitude should failure occur. A decision gate must be devised at, say, 50 ft above the runway. If failure occurs prior to the decision gate a go-around procedure is initiated. If failure occurs after the decision gate, the backup information is used to make the landing. This concept of fail-safety is believed satisfactory with the present approach angles of 3 deg or less.

Pilot opinion of the system indicates that the ground point intercept of the glide slope would probably have to be moved back to the approach end of the runway for automatic flares unless touchdown of 2000 ft beyond the approach end of the runway is allowed. Pilots tend to overide the landing system even when it causes the plane to maneuver in a manner not unlike the results of their own handling. A pilot supervising an automatic landing system prefers it to begin the flare slightly before he himself would. This would allow him time to take over in the event of a malfunction.

■ **To Order Paper No. 348B . . .**
from which material for this article was drawn, see p. 6.

Gas Sampling Valves Measure Scavenging Efficiency

Based on paper by

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University of Tokyo

and SIGERU YANAGIHARA,
Government Mechanical Laboratory (Japan)

TWO types of quick-acting electromagnetic gas sampling valves — needle and poppet — have been developed to measure the scavenging efficiency of high-speed 2-stroke engines.

The needle type, shown in Fig. 1, consists of a plunger-type electromagnet and a needle valve. The latter usually is closed against the maximum cylinder pressure of 30–40 kg/cm² (427–569 psi). It can be opened for a short time only by the electromagnetic force.

The upper part of the valve makes a condenser-type pickup *1* to detect the valve motion. Solenoid *3* is a coil wound with about 130 turns of 0.8-mm copper wire. The attractive piece *5* is pure iron, with an effective area of nearly 3 cm² (0.465 in.²). There are two gas outlets *7*, to avoid throttling of flow. The needle valve *8* is usually pressed to the seat against the cylinder pressure by a helical spring *6*, whose initial force is 7–18 kg (15.4–39.6 lb), and is lifted for a moment by the attractive force of the iron *5*. The gas inlet *9* has an inner diameter of 5 mm.

To control the valve actuation, a few electronic devices are needed. The signal to open the valve is picked up from the crankshaft directly through the photocell fixed at a certain crank angle and, if a suitable delay circuit is used, the signal is shifted to any crank angle corresponding to the engine speed. On the other hand, an electronic counter may be available to reduce the signals at every revolution to those at the suitable interval without delay.

Fig. 2 shows the schematic arrangement of this apparatus to actuate the sampling valve. *1* is the sampling valve, *2* the test engine, and *3* the spark plug being missed automatically by a relay *10* when the charged gas is extracted. *4* is the crankshaft on which signal pickups (slit or mirror) are equipped, *5* is a photocell, whose signal is used to synchronize the sweep of an oscilloscope *12* with the crank angle. *6* is the same type of pickup to start the valve-opening signal, whose timing is fixed. Therefore, in order to shift the valve opening timing arbitrarily, a delay circuit *7* is inserted between *6* and an electronic counter *8*, which reduces the signals at every revolution of the crankshaft to one- or a half-hundredth, and *9* is the impulse current circuit. The valve-opening timing and duration can be regulated, respectively, by the delay time in *7* and the discharge capacity in *9*, monitoring the signal current and valve movement on the oscilloscope *12*.

When cylinder pressure is high, say, over 100 kg/cm² (1422 psi), as in a diesel engine, it is difficult to make the needle-type sampling valve close. In addition, the effective valve area cannot be made great enough so that the composition of extracted gas will indicate precisely the average in the cylinder.

This problem is solved with a poppet-type valve that can operate against high cylinder pressure and can extract a greater volume per cycle. This valve is closed by the spring force and is opened by the electromagnetic force, as is the needle-type valve.

The construction of the poppet-type valve is shown in Fig. 3.

■ **To Order Paper No. T47** . . . from which material for this article was drawn, see p. 6.

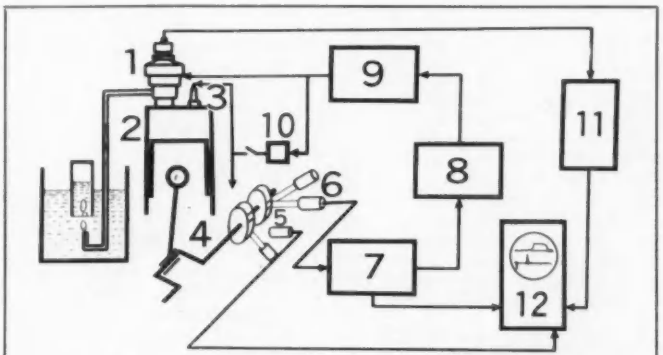


Fig. 2 — Arrangement of apparatus: *1* gas sampling valve, *2* engine, *3* spark plug, *4* crankshaft, *5* signal pickup (to sweep), *6* signal pickup (to valve open), *7* delay circuit, *8* electronic counter, *9* impulse current circuit, *10* relay, *11* transducer, *12* oscilloscope.

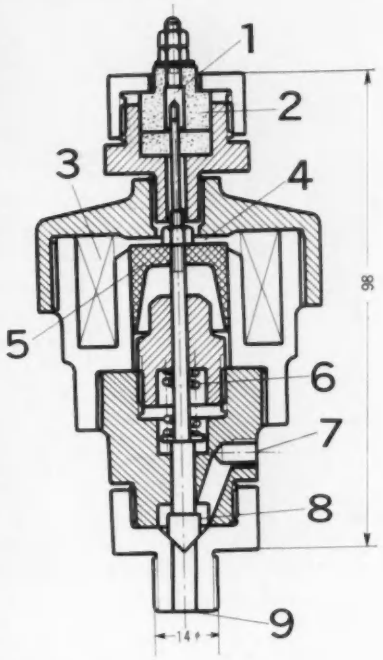
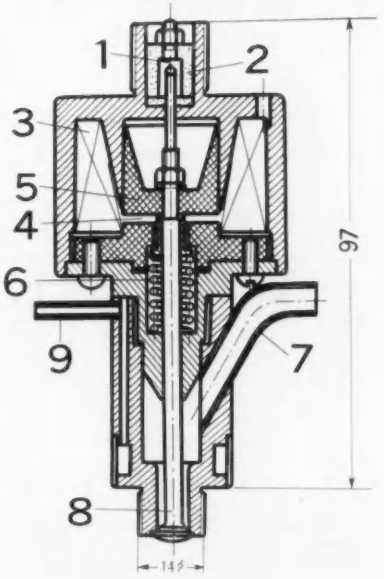


Fig. 1 — Needle-type gas sampling valve: *1* condenser pickup, *2* insulator, *3* coil (solenoid), *4* air gap (lift), *5* pure iron piston, *6* spring, *7* gas outlet, *8* valve, *9* gas inlet.

Fig. 3 — Poppet-type gas sampling valve: *1* condenser pickup, *2* insulator, *3* coil (solenoid), *4* air gap, *5* pure iron piston, *6* spring, *7* gas outlet, *8* valve, *9* cooling water pipe.



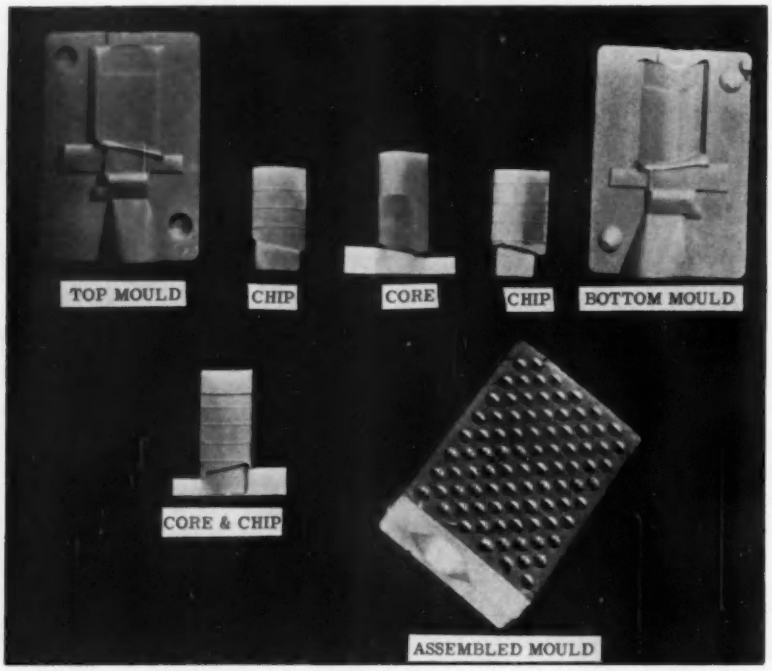


Fig. 1 — Components of the 5-piece ceramic mold, for producing internally finned turbine airfoils, are all made of one material and are formed by injection molding. The chips separate the core from the top and bottom mold during the curing of the assembly and its subsequent transfer to the foundry. After the chips have been removed and the mold reassembled, the metal is poured directly into the mold.

Preformed Cores Form Hollow Turbine Airfoils

Based on paper by

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Allison Division, GMC

and

J. H. REED
Central Foundry Division, GMC

PRODUCTION casting of long thin-wall hollow turbine airfoils is achieved using performed, soluble cores made of Alsimag 145 material. Hollow airfoils with intricate geometry are made using cores of this material and casting by the investment, vacuum, or centrifugal method. So, the airfoil designer may select internal passages with twisted, tapered, and dumbell type configurations, to give efficient use of the cooling air volume. When casting by this method, wall thicknesses may be controlled to as low as 0.020 in., and, if desired, further reduction by solution machining is also possible. Any of today's heavy alloys can be cast by this technique.

Alsimag 145 material can be formed economically into straight, tapered, or twisted cores for hollow castings . . . which can be made to withstand the the rigors or normal foundry handling, yet are readily removed from the finished casting by immersion in molten caustic.

To make the core of the desired dimensions, on a production basis, it is injection-molded in a die equipped with retractable plates. The plates are inserted into the die cavity during the injection of the core material and removed prior to the opening of the die. The resulting impressions in the core, in turn, form fins on the cast airfoil for effective heat transfer. This method eliminates the need to remove the soft ceramic core from an intricate injection die configuration.

After the cores are made they are cured on molds of the same material. The curing or "setting-block" is injection-molded also. Both it and the core are made with shrinkage allowance to give better dimensional control and reproducibility.

By making the setter-blocks to the external casting dimensions and introducing two ceramic plates or chips, equal to the wall thickness of the casting, between the core and the blocks the entire mold may be made at once. The five ceramic parts, shown in Fig. 1, are injection-molded at the same time from the same material and assembled before drying and firing.

The completed package is shipped to the foundry where it is opened and the chips discarded. The mold is then reassembled and the metal poured directly into the mold. This technique aids in dimensional control of the thin cast airfoil shell and reduces the accumulated processing tolerance buildup at the foundry. It also allows the production of the airfoils to be adapted to automation. The small size of the resulting mold makes it adaptable to centrifugal or vacuum casting. In addition, the usual investment processing of the lost wax method is eliminated and the mold preheat time is reduced from 12 to ½ hr.

The successful casting of long, thin-wall, hollow turbine airfoils, has allowed the designer to reduce the danger of thermal shock cracking by controlling the differential expansion between sections of the airfoil. By passing cooling air within the airfoil, a greater reduction of thermal shock cracking is realized and also the operating gas temperature of the airfoil can be increased without reducing the endurance life of the parts. By adjusting the airfoil configuration to improve internal heat transfer characteristics, the required amounts of cooling air from the compressor would be reduced, resulting in increased power output and a reduced specific fuel consumption.

The soluble core method of casting may also be applied in the production of similar parts, such as fuel controls, thermocouple probes, and pitot tubes.

Accurate inspection of these parts, without which the use of this method would be inhibited, is made possible by the use of radioactive materials. The inspection technique which has been developed can reach an accuracy of ±0.001 in. The technique involves injecting an isotope-bearing solution into the airfoil and measuring the radiation attenuation at several points, with a geiger tube.

■ **To Order Paper No. 280B . . .** from which material for this article was drawn, see p. 6.

Wanted NOW— A True Cargo Airplane

Based on paper by

EMERY JOHNSON
Air Cargo, Inc.

FIFTY-ONE years after the Wright brothers' first flight and 31 yr after the beginning of commercial air trans-

port, aviation stands unique in failing to develop different types of vehicles for freight and passengers. We are still beefing up the floors of passenger transports and calling them cargo airplanes.

When true cargo aircraft are projected for the future, the talk is always about still bigger aircraft so that ton-mile operating costs can be lowered. But there is real danger in pursuing "size." Offsetting disadvantages will be picked up along the way. Depreciation will increase, terminal and handling requirements will expand, and the upshot will be a loss of mobility and flexibility.

Flexibility Is Vital

If air traffic becomes set in a rigid pattern between a few fixed terminals, the density of traffic may not always suffice, and there won't be any escape. If carrying commodities in bulk between a few high-density points is *not* the role of cargo aviation in the future, then we may put ourselves out of business before we really get into it.

All forms of commercial transportation must face the fact that population and industrial plants are becoming decentralized and moving away from high-density cities. This trend will be accelerated by interstate highway construction, and motor truck carriers will reap the benefits because of their flexible operations. The railroads lost out to the motor carrier because they were handcuffed to their steel rails, and any other mode of transportation lacking mobility and flexibility will be similarly handcuffed.

Design for Continental Operation

The high cost of research and development has trapped us into thinking we can build a single airplane which will be all things to all people — a vehicle to fly the Atlantic and Pacific nonstop, land at the South Pole, air drop over Berlin, and still earn money carrying household appliances from Mansfield, Ohio, to Mobile, Ala. We would do better to think of developing a good cargo airplane for commercial operation within the U.S.A. which is a land of more than 54,000 communities and not a sea of water.

Subsidy for cargo operations has been suggested as one way to spur development of a true cargo airplane. Guaranteed loans have also been proposed, as well as legislation similar to that aiding the maritime industry. Some branch of government might legitimately participate in the initial cost of development as a spur to new productivity and to foster higher economic growth. Affirmative action would aid both manufacturers and operators and help to create an entirely new frontier in the sky.

■ **To Order Paper No. 335D . . .**
from which material for this article was drawn, see p. 6.

LEWIS Scientists Update Knowledge of New Areas

Based on paper by

EUGENE J. MANGANIELLO and VINCENT F. HLAVIN
Lewis Research Center, NASA

AT NASA's Lewis Research Center in Cleveland some 800 research scientists and engineers have matured professionally in an environment which is one of continuous learning. Their experience comes close to being a form of postgraduate training in itself.

But even in so favorable an environment, many special steps are required to keep these men capable and effective throughout the full range of new and advancing sciences and technological fields. Throughout NASA's 18-year history, its staff's principal areas of interest have had to be constantly reoriented.

Always, NASA's Lewis Research staff has been encouraged to improve educational backgrounds through on-the-job seminars, brief, specialized lecture courses, and attendance at graduate evening course provided by local colleges. But only since 1950 has financial support for these increasingly needed educational activities been possible. In the 1950–1951 school year, seven NASA scientists and engineers participated in the limited program of college courses involved in a $10,000 training budget made available by the then-new NACA Graduate Study Leave Act passed by Congress. Now more than 50 researchers are participating in a $31,000 program.

In addition, however, Lewis Research Center has had to expand its own informal seminars and lectures into a series of formal graduate-level courses on subjects not available at colleges. The "students" in these courses now total around 400 — as against 150 in 1953, the first year of the expanded program's operation. These Lewis Research Center courses serve the needs of those interested in supplementing their education without enrollment in formal graduate programs . . . or of those financially unable to attend graduate school under the limited support program available.

An important secondary result of these Lewis Research Center facilities for permitting continued education is the favorable effect in attracting young college graduates. Today's superior student, who strongly desires to enter the research field, usually has an equally strong desire to continue his educational program. So, on-the-job educational possibilities of this kind attract him. . . . But NASA's Lewis Research Center doesn't encourage graduate study as a fringe benefit for new recruits. Its primary incentive is to the senior staff.

In any technological industry, continuing education is an important part of the overall picture.

If science and technology are to continue as a major aspect of our way of life; if manpower shortages persist in critical skill areas; if we are to retain our present competitive position . . . then employers must ensure that the immediate educational needs of technical staffs are met; and make provision for future needs.

■ **To Order Paper No. 314A . . .**
from which material for this article was drawn, see p. 6.

VERSATILITY Top Quality For Engineer of Tomorrow

Based on talk by

J. J. MIKITA
du Pont Petroleum Chemicals Division

VERSATILITY, basic engineering knowledge, ability in the humanities, and ability to design creatively are major educational needs for tomorrow's engineers.

Versatility is the one characteristic most likely to differentiate tomorrow's engineer from today's. Vast outpourings of scientific research and rapidly changing technology will require this attribute in the future. The engineer will have to be able to move from one field of technology to another . . . and to produce useful engineering results quickly.

The engineer of tomorrow will have an increasing need for knowledge of the basic sciences. He will need to communicate effectively with scientists. He will have to take his place next to scientists as an equal, and abandon the secondary role which many engineers play today.

Engineers also have more than a passing responsibility to society. Their creations affect the lives of everyone. Along with scientists, engineers already play a profound role in influencing our way of life. And engineers of the fu-

Continued on next page

ture must assume greater leadership in our social and economic problems.

Creative design is one of the highest forms of engineering technology . . . and the creative designer of tomorrow must have an extraordinarily good working knowledge of the basic sciences and the engineering sciences. He must understand materials. He must know how to use his knowledge to synthesize what he seeks.

Such an engineer will be too valuable to use in repetitive work.

Also, this engineer of tomorrow should be equipped to assume responsibility and leadership in the affairs of industry and the community. Finally, it is to be hoped that more of the engineers of tomorrow will develop into technological statesmen.

Fuel Burning Rate Big Factor in SI Valuations

Based on paper by

V. J. TOMSIC
du Pont Petroleum Laboratory

A FUEL'S burning rate may affect its surface-ignition behavior more than its intrinsic resistance to surface ignition, a recent du Pont Petroleum Laboratory study indicates. The study gave special attention to checking the rate at which the air-fuel mixtures were consumed (the burning rate) as well as the resistance of the fuel to ignition. The two factors were studied together.

The importance of differences in burning rates is especially significant, du Pont researchers found, when evaluating the tendency of a fuel to cause an engine to rumble. Other conclusions reached from this study include:

Methods of measuring surface ignition using fixed time gates, as common in the past, may reflect differences in burning rates to a greater degree than differences in ignition resistances. This is particularly true when the incidence of surface ignition is low.

The LIB reference fuels are not suitable for measuring the intrinsic surface ignition resistances of other fuels. . . . But they may help in studying the tendency of a fuel to cause rumble.

Differences in ignition resistances and burning rates are quite small for commercial-type fuel blends. But, inclusion of alkylate in the blend appears to improve surface-ignition behavior.

Surface-ignition ranking of fuels may be influenced by the type of deposit used to induce ignition. Also,

Continued on page 127

Briefs of SAE PAPERS

continued from page 6

and A. B. Croshere, Jr. **Paper No. S292.** Gives analysis showing that air travel is mostly over short-range flight segments; that market has peculiar characteristics which require aircraft specially designed to serve it; and that such designs are feasible — and will be available.

VTOL Aircraft, THOMAS C. MUSE. Paper No. S286. Discusses possible VTOL uses in military applications . . . currently, in light of current research, and in light of problems. Sees operational VTOL aircraft (other than helicopters) in military services in late 1960s or early 1970s. Brief review-type treatment.

GROUND VEHICLES

Evolving City, C. A. BLESSING. Paper No. 266B. Problem of rationalizing urban development in United States during next generation and planning to shape city of future; responsibility of automobile industry in establishing urban space research center to study solutions to transportation and related land use patterns of urban regions; study of transportation systems should take into account environment which transportation serves and in which it functions; steps required for substantial research goal in transportation field.

Creative Approach to Body Surface Development, R. TERRY, R. LEASIA. Paper No. 271A. Technique, evolved by Creative Industries of Detroit lessens cycle time for die model construction and provides shortcut approach, eliminating some of conventional steps or directly reversing information flow in body surface development; as result there is only one step between clay model and final approved 3-dimensional master model; information recorded is traced from templates taken from latter; this allows immediate start on developing flange, holes, and cutout information.

Two New Hydra-Matic Transmissions for 1961, W. B. HERNDON. Paper No. 290A. Features of General Motors Model HM 61-10 designed for conventional automobiles, and HM 61-5 for smaller cars; transmissions are similar in design and operating characteristics except for size and torque capacity; HM 61-10 is fully automatic, has three gear speeds, plus torque multiplying fluid coupling which gives transmission ratio coverage equivalent to 4-speed transmission, with only two shifts instead of three; fluid coupling, and power flow; major differences of HM 61-5.

New Buick Special Automatic Transmission — Dual Path Turbine Drive, C. S. CHAPMAN, R. J. GORSKY. Paper No. 290B. Factors receiving special attention in selection of transmission type were package size, weight, cost, and compatibility with Buick marketing emphasis on smoothness; details of power flow and transmission arrangement; hydraulic controls; component fabrication; oil sealing; effect of dual path arrangement on friction elements and carrier; schematics, illustrations.

Accelerated Testing at Fiat Laboratories, C. F. BONA, L. LOCATI. Paper No. 292A. Features of organization, devoted to research of automobile and aviation materials; how it offers comparisons and allows transfer of test methods from one field to other, as exemplified by evaluation of body modes of vibration using ground resonance test methods of aircraft structures, and M. A. MINER's principle of cumulative damage; property determination, and endurance tests; acceleration factors for two types; basic research assisting in solving problems of tests acceleration.

Front Suspension — Analytically Speaking, R. R. LOVE, A. D. BOSLEY. Paper No. 295B. Procedures and tools used by Chrysler Corp. in developing suspension; basic variables affecting camber control are control arm length and knuckle length ratio, control arm starting angle, and absolute length; front suspension geometry layout is analyzed with digital computer program which determines properties of linkage; 4-unit program builds up background with complete geometry; details of force analysis which calculates forces on front suspension when applied anywhere to tire.

Improved Analog for Vehicle Stability Analysis, F. N. BEAUVAIS, C. GARELIS, D. H. IACOVONI. Paper No. 295C. Objective of 5-phase program at Ford Motor Co. is to develop method for designing vehicle that provides driver with optimum control un-

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der any condition; present vehicle analog used and refinements such as use of nonlinear tire characteristics; computer steady state and transient response data for typical analysis; special test instrumentation and techniques for experimental substantiation and correlation between vehicle and computer results.

Multifuel Engine Practice, J. S. MEURER. Paper No. 296A. Experiences gained at MAN, Nuremburg, Germany with regard to "M" combustion process as applied to straight diesels, and improvements obtained during past 5 yr with emphasis on multifuel engines; general features of multifuel engines, combustion process, influence of engine speed, and compression ratio, adjustment of injection pumps, special design problems, and starting characteristics of M-type engines at low ambient temperatures.

New Single-Piston Injection Pump "Silto" and Its "Liquid Stop" Governor System, P. BESSIERE. Paper No. 296B. Details of Silto pumps of single distributing piston type, for high speed diesels, built by Precision Mécanique Labinal, Paris, France; hydraulic regulator employs self-regulating principle of Liquid Stop which is explained; operation of latter is unusually accurate; between two successive injections, spacing of plunger on its Liquid Stop is less than 1/100 mm, even at very high speed (4 cyl engine rotated at 5000 rpm); operation of pump.

Army's View of Future, A. G. TRUDEAU. Paper No. 297A. Principal advantages of gas turbine for military use and outline of U. S. Army's active development program dealing with following areas: development of power boost units for use in conjunction with reciprocating or diesel engines, auxiliary units for use in cold-starting kits, main power plants, and small turbines in ½ to 20-hp field.

On Cavity Resonance of Car Room and Its Abatement, H. NAKAMURA, S. SATO, J. SAKAGAMI. Paper No. 298A. Experiments at Nissan Motor Co., Ltd, Yokohama, Japan, to study vibration modes of cavity resonances of car interior using 2-dimensional model; to prevent cavity resonances, effects of Helmholtz resonator were studied theoretically and experiments carried out using models; cavity resonance and its prevention in actual car were studied based upon results of model tests; results obtained for various frequency ranges.

Strength and Rigidity Requirements for Automobile Structure, M. YAMAMOTO. Paper No. 298B. Reference is made to establishment of strength requirements by SAE Committee in Japan in 1949; experience showed necessity of revision of requirements, and in 1955 committee decided to conduct necessary experiments; paper contains resulting recommendations for strength and rigidity calculations and for estimation of loads on vehicle, compiled over 5 yr period.

Van Container Standardization — Goals, Problems and Progress, K. W. TANTLINGER. Paper No. 299A. Review of progress made toward container standardization and new techniques offered for transportation and handling of shipping containers; example of 20 ft container, 8 × 8 ft in cross section, weighing 3500 lb and capable of transporting 1130 cu ft of cargo from road to rail to water and air; analysis of present and future needs and main requirements of proposed design for standardized shipping containers for maximum interchange.

Container Development in Railroad Industry, N. E. BATESON. Paper No. 299B. Development of containerization predicated on integration of all modes of transportation; efforts made by railroads as exemplified by Plan 1 of trailer-on-flat-car service transporting loaded trailers or semitrailers of motor carriers over rail; cars designed for piggybacking; equipment for piggyback and containers such as 85-ft car with stanchions for trailers folded down; methods of loading and unloading, cranes and unloading devices used.

What Operator Wants in Containers, E. B. OGDEN. Paper No. 299C. Viewpoint of Consolidated Freightways summarized with regard to standardization of container sizes, methods of handling between highway, rail, and water; consideration of lower container rates than semitrailers of same size, when tendered to other forms of transportation, because of weight reduction of wheels, axles, and springs removed.

Effect of Fuel Cell Power Plant on Future Automobile Design, B. STEVENS. Paper No. 303A. Outline of general concept for low priced high volume mass produced vehicle based on assumption that fuel cell power plant in compact form can be located in strategic areas of skin and that vehicle would cover needs of transportation for all people; feasibility is foreseen for 1970.

Ausco Oil Cooled Truck Brake, D. A. GOTSCH. Paper No. 304A. To meet fleet operators' requirements Auto Specialties Mfg. Co. developed truck brake retarder combination unit incorporating emergency brake; oil cooled multiple disk brake is completely sealed and cooling oil in contact with friction surfaces at all times; heat generated during braking and retarding is rejected to engine radiator through separate brake oil cooling system; details of cooling system, installation, cast and disk wheel model; hydraulic system; test results.

Disk Brake Development and Anti-Skid Braking Devices, J. W. KINCHIN. Paper No. 304B. Development of disk brakes for aircraft and introduction of these on motor cars, particularly, heavy high speed range and racing cars; first types of brakes, made by Dunlop Rubber Co., England and other makes. Basic design, performance and advantages; description of various antiskid units, test results and advantages.

Trends in Development of Vehicle Brakes and Anti-Skid Braking Devices in Europe, H. STRIEN. Paper No. 304C. Design is influenced by definite vehicle factors, traffic and road conditions; relations which led to development of disk brakes and braking effort control devices; trends observed toward use of same brakes on front and rear axle with little or no self energization and installation of control valves (pressure limiting, boosting and pressure reducing types) so as to approximate braking effort to dynamic axle loads.

Test Tracks for Vehicle Tractive Ability Testing, D. C. BAILEY. Paper No. 305A. Background and construction details of tractor test tracks built by Military Eng. Experimental Establishment, Christchurch, England; specifications of materials used such as rubberized bitumen, grit sand, soft limestone, hard limestone, clay, and specification of mixes; special technique developed for mixing rubberized bituminous clay based on theory, which is given; method of laying.

Search for Perfect Engine Air Cleaner, G. L. A. COATES, E. V. TULL. Paper No. 305B. Study, made by Military Eng. Experimental Establishment, Christchurch, England to determine most harmful sizes of dust particles in relation to engine wear, particularly for earthmoving equipment used by services under dusty conditions; prototype self cleaning air cleaner and 150-bhp 4-stroke diesel engine was used for tests; dust analysis; dust chamber and instrumentation; features and operation of cleaning mechanism; construction of elements; test results.

Service Equipment with Transistorized Ignition, J. F. GAGE, C. J. DUNNE. Paper 306A. Results of 1-yr field operation of transistor ignition system, developed by Electric Autolite Co., Toledo, Ohio; design details of system; program included trucks, buses, highway patrol and private cars, and stationary engines; data on contact life to date based on cross section of field installations; it is found that transistor systems have reduced contact "bluing" and erosion and increased contact service life.

American Motors New Die Cast Aluminum Engine, J. F. ADAMSON, C. E. BURKE, D. V. POTTER, W. J.

Briefs of SAE PAPERS

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ZECHEL. Paper No. 307A. Design and material considerations incorporated into preliminary A-design and die casting techniques; centrifugal cast iron liner with rough outer surface proved to be ideal for die casting; details of final B-design which has deeper crankcase skirt for greater main bearing rigidity, overall block stiffness and better transmission support; main bearings; nature of aluminum and fatique life; tensile and bending tests; corrosion.

New Buick Aluminum Engine, J. D. TURLAY, E. H. HOLTZKEMPER, C. G. STUDAKER. Paper No. 307B. 8-cyl V-8 engine was chosen to power new Buick Special; cylinder block and heads are made by semi-permanent mold process; intake manifold is made as sand casting, and die castings include such components as timing chain cover, water pump cover, etc; details of combustion chamber cooling and lubrication system; crankshaft, fuel system and engine ventilation; results of 10,000 hr of dynamometer testing and 1,000,000 mi of operation in test cars.

Chrysler Corporation's Die-Cast Aluminum Slant Six Engine, E. G. MOELLER, W. L. WEERTMAN, H. E. ERIKSEN. Paper No. 307C. Weight reduction achieved by introducing die-cast aluminum cylinder block, alternator, and die-cast aluminum oil and water pumps; 6-cyl engine has 3.40 in. bore and 4.12 in. stroke, compression ratio of 8.2:1 and is tilted 30° to right; design background and development of 225-cu in. engine with emphasis on die-cast aluminum block; casting and machining considerations; engine performance.

Oldsmobile F-85 Aluminum Engine, G. BURRELL, F. BALL. Paper No. 307D. Features of F-85 automobile designed around new, all aluminum V-8 "Rockette" engine, power requirements of which were based on car weighing 2700 lb and having performance to match 1960 Oldsmobile Dynamic 88; electronic computer was used to determine torque curve required; basic features of 215-cu in. engine, combustion chamber, intake manifold, pistons and rings, cylinder heads, valve mechanism, and crankshaft; engine cooling and lubrication system; carburetion and fuel system.

Pontiac's New Four-Cylinder Tempest Engine, J. P. CHARLES, M. R. McKELLAR. Paper No. 307E. Engine which is result of program for design and evaluation of several line and vee engines of 6 and 8-cyl type in aluminum and iron for smaller car market; general arrangement and interchangeability of parts and assemblies; cylinder block and head; valve gear, crankshaft and main bearings; lubrication and engine cooling; engine dynamics and balance; fuel requirements.

Bus Operation and Maintenance in United States Yesterday — Today — Tomorrow, F. N. HATCH. Paper No. 309A. Four types studied are city, suburban, intercity motorbus, and school bus; operation with respect to trends in use of automotive vehicles, production of buses, and miles operated; trends in maintenance, opinions and predictions based on information gathered from trade magazines, bus companies, associations, city, county, state and federal agencies; graphs and tables.

European Bus Developments, N. E. NYSTROM. Paper No. 309B. Review of general trends after World War II with special attention to integral construction vs. separate chassis and body construction, engine location, type of engine, transmission, and suspension, and styling; examples of latest designs by leading manufacturers; possible trends for future are predicted from road designs and traffic, safety and health regulations, competition from passenger cars, and operating and maintenance requirements.

Dynamic Wheel Loading, P. KOESSLER. Paper 310A. Main road stress and damage result from vertical loads consisting of three elements in respect to each wheel; positive and negative dynamic supplementary loads, as result of vehicle vibrations caused by driving over obstacles; five measuring methods, developed in various institutes in Brunswick, Munich, Darmstadt, Hanover, and Aachen, West Germany, by means of which supplementary load can be determined; tests carried out using method developed at Inst. for Vehicle Technology, Brunswick.

Preliminary Investigation Into Dynamic Behavior of Vehicles and Highways, D. C. CLARK. Paper No. 310B. Analysis of basic problems in analytical treatment of road loading mechanics; research program recommended to place highway-vehicle system on quantitative analytical plane, substantiated by experiment; results of first sub-study, development of preliminary dynamic vehicle mathematical model; how mathematical model indicates important parameters that must be measured in experimental program.

Influence of Road and Vehicle Dimensions on Amplitude of Body Motions and Dynamic Wheel Loads — Theoretical and Experimental Vibration Investigations, M. MITSCHKE. Paper No. 310C. Study at Inst. for Vehicle Technology, Brunswick, West Germany, concerned with vibratory motions of automobiles traveling over rough roads; how magnitude of motions depends on vehicle construction and on roughness structure of road; equivalent vibration diagram of automobile; evaluation criteria; comparison of theory and test results.

Ratio Changing Passenger Car Automatic Transmission, F. J. WINCHELL, W. D. ROUTE. Paper No. 311A. Annoyances attending automatic shift or ratio change; nature of disturbances; types of ratio change; factors affecting degree of disturbance, largest single of which is the size of ratio; gear train and engaging elements; graphs indicating range of element application for 2 and 3-speed arrangements; mechanics of ratio changing; equations for simple planetary train; clutch energy equations.

Automatic Transmission Friction Elements, L. E. FROSLIE, T. MILEK, R. W. SMITH. Paper No. 311B. Paper concerned with cone clutch, single and double wrap bands, and single or multiple disk clutches; types are discussed in order of increasing ability to absorb and dissipate quantities of energy; theoretical analysis, description, design considerations, manufacturing process, testing procedure and operational problems relating to each type.

Transmission Oil Pumps. Paper No. 311C. Contributions, by General Motors, Chrysler, and Ford Motor Co., intended to give complete understanding of design requirements and current design practices used in industry. Application of Oil Pumps to Automatic Transmissions, J. R. DOIDGE, 1–2; Internal-External Gear and Internal-External Rotor Pumps for Transmissions, L. E. FROSLIE, 3–10; New Transmission Slipper-Type Pump, J. W. GUTERMAN, 11–15; Variable Capacity Transmission Pump, R. W. STAPLETON, 16–21.

Corvair 95 — Chevrolet's Space Age Panel Truck, A. C. MAIR. Paper No. 313B. Range of Chevrolet's new light-duty line, built on 95-in. wheelbase and rated at ½-ton; models feature body-frame integral construction, transaxle design with standard 3-speed or 4-speed or Powerglide transmission, rear mounted 6-cyl aircooled engine and 4600 lb max. GVW rating; how concept and objectives were met in actual design and production.

Light Truck Development in Bell System, J. MacDOUGALL. Paper No. 313C. Bell System Motor Vehicle Fleet

has 60,000 trucks in half-ton class, most of which are equipped with special body designed for utility work, installation and maintenance of telephones used; requirements of trucks and equipment which must be carried; experiments made with various types of trucks, including foreign models; results of analysis reviewing company's need and introduction of Corvan and Econoline van.

Gas Sampling Valve for Measuring Scavenging Efficiency in High-Speed Two-Stroke Engines, T. ASANUMA, S. YANGAGIHARA. Paper No. T47. Characteristics of two electromagnetic valves (needle and poppet valve) developed at Univ. of Tokyo; valves can be actuated during 2 or 3 msec, so that it is possible to extract sample gas from cylinder of engine running at 6000 rpm; since duration of sampling can be controlled very finely by changing discharge capacity, total valve-opening angle can be maintained constant at any engine speed.

No Zero Shifting Developed Higher Performance Strain Gage Type Engine Indicator, S. MATSUOKA. Paper No. T48. Requirements for pressure indicator and defects of previous designs, in particular air cooled type of indicator, developed by C. S. DRAPER and Y. T. LI, (see Engineering Index 1949 p. 572); water-cooled improved strain-gage pressure receiver; how stabilization and improved performance of indicator is achieved; with regard to problem of pressure, temperature, and insensitivity to vibrations, effective method for calibration is proposed.

Electronic Device for Measuring Indicated Mean Effective Pressure, S. OHIGASHI, I. HIGASHINO, T. TSUKISHIMA. Paper No. T49. Details of direct reading instrument developed at Osaka City University, Japan, which consists of pressure pickup, automatic calculating apparatus, and digital indication system; it has sufficient accuracy and reliabliity for practical use in study of engine characteristics; summation of sampled data; discrimination of positive and negative work and performance; results of accuracy tests.

Payload and Performance with Aluminum. W. C. WELTMAN, Jr. Paper No. S287. Gives examples to prove basic economic advantage of lightweight aluminum earthmoving equipment. Claims economics in favor of aluminum are more impressive today than in 1932. Examples are of equipment actually in use and include data about their performance.

Military Multifuel Compression-Ignition Engines and Their Fuel Requirements. ERROL J. GAY. Paper No. S289. Reviews fuel-engine problems of U.S. Army, citing Korean and other war experience. Discusses three "multifuel" engines currently being field-tested by Army. Sees much promise in compression-ignition fuel. Says: "It may become major source of energy for Army engines in the time frame 1960–1970."

Objective-250,000 mile Truck. GALE R. BEARDSLEY. Paper No. S295. Shows — with illustrations — the design actions and test programs associated with achieving durability objectives for Ford's new H-series highway tractor.

FUELS & LUBRICANTS

Abnormal Combustion at Engine Cranking Speeds, R. S. SPINDT, D. R. O'MALLEY. Paper No. 293B. Study shows that preflame reaction behavior of fuels affects hard cranking characteristics of engine; pressure records give evidence for reactions accompanied by degenerate explosions and/or autoignition; fuels tested and temperature data obtained in test car studies; data suggest that evaluation of fuels for hard cranking resistance might be done more accurately in single cyl. engine; efforts to develop test procedure in modified CFR engine.

Study of Normal and Abnormal Combustion Behavior of Gasolines, V. F. MASSA. Paper No. 293C. Study by Esso Research Co. relating to abnormal phenomena such as surface ignition and rumble was made by observation of distribution of flame arrivals at ion gaps located within engine cylinders, or peak pressure position, in terms of crank angle degrees; abnormally high peak cylinder pressures giving rise to rumble result from cycles in which combustion occurs early; early combustion was caused by deposit-ignition of charge but also affected by its mass burning rate.

New Insight into Mechanism of Surface Ignition, J. A. ROBISON, R. G. MOSHER, W. K. OJALA. Paper No. 293D. Relative order of fuels in hot-spot ignition resistance is not same order in relative deposit ignition resistance; study made at Ford Motor Co. to assess factors responsible for rearrangements in relative order of fuels; it was found that hot spot ignition resistance is controlled solely by temperature required to ignite fuel mixture; deposit ignition resistance is controlled by surface heating ability of fuel; neither of characteristics are completely understood.

Surface Ignition Behavior of Fuels, V. J. TOMSIC. Paper No. 293E. Study made by Petroleum Laboratory of E.I. duPont de Nemours & Co. considers intrinsic ignition resistances of fuels and their burning rates by analyzing pressure development during combustion in engine; it is found that differences in burning rates may be of more importance than differences in intrinsic surface ignition resistances, particularly in presence of powerful ignition sources;" other findings.

Measurement of Flame Temperatures in Gasoline Engine, K. NAKATA. Paper No. 293F. At Transportation Tech. Research Inst., Tokyo, Japan, flame temperature was measured at three positions in engine, near plug, at center, and at spot where burning was most retarded; engine of larger type was chosen to obtain stable running for wide range of driving conditions; basic idea of measurement; method of measurement and corrections made for flame temperature; summary of results and interpretation.

Mechanical, Sonic, Ultrasonic, and Radiation Studies of Polymer-Thickened Oil Shear Characteristics, R. P. NEJAK, E. R. DZUNA. Paper No. 294C. Four laboratory shear test procedures evaluated at Gulf Research & Development Co. as replacements for SAE 71R recommended pump shear test for central hydraulic system fluids; eight fluids evaluated; ASTM sonic test is not particularly effective; full power sonic test has prospects; ultrasonic test can be used in good agreement with pump shear test; radiation has potential.

Low Temperature Cranking and Flow Properties of Waxy, Polymer-Thickened Motor Oils, H. H. HOROWITZ, G. K. VICK. Paper No. 300A. Study of possibility that wax may interact with polymer in multiviscosity grade oils to raise viscosities; series of cold cranking tests were run in passenger car engine on lube stocks dewaxed to varying degrees with and without polymers added; techniques used at Esso Research and results obtained on plate-cone viscometer showing possibility of improving SAE classification system for winter grade motor oils.

Extended Chassis Lubrication Periods for 1961 Ford, Lincoln, and Mercury Cars. C. L. KNIGHTON and R. I. POTTER. Paper No. S285. Shows progress in chassis lubrication has come slowly. On 1961 Ford, Lincoln, and Mercury chassis grease fittings have been eliminated, and the joints are factory-lubricated and sealed for extended service period. Basic design of ball joint and steering linkage has not been changed. Lubrication has been eliminated by using lifetime seals of new materials, combined with prepacking chassis components with improved lubricating greases.

Supersonic Jet Fuels — Quality and Cost Factors. W. G. DUKEK. Paper No. S288. Shows why quality features needed in a supersonic fuel will tend to make it more expensive than current fuels, but indicates that this cost can be kept within the desired economic boundaries by design com-

Briefs of SAE PAPERS

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promises in the air frame . . . such as insulation to reduce thermal stress, supplementary coolers to reduce the fuel sink load, and use of inerted and pressurized tanks.

MATERIALS

Studies of Friction Phenomena Using Radioactive Tracers, P. KOESSLER. Paper No. 289B. Two phenomena are distinguished during running-in of brake fitted with new lining: adaptation of form of lining to drum until "carrying" of lining is obtained, and elimination of so called "infection"; experiments at Institut fuer Fahrzeugtechnik, Braunschweig, Germany, relating to transfer of matter from brake lining to brake drum, transfer of matter from radioactive brake lining via drum to nonradioactive lining; results obtained.

Effects of Ionizing Radiation on Organic Materials, J. H. FUTRELL. Paper No. 294D. Characteristics of ionizing radiation with particular reference to interaction with matter; it is shown that chemical effects of ionizing radiation are function not only of radiation but of chemical system being studied; use of ionizing radiation in field of polymer chemistry; examples and potential uses are outlined to show that radiation can be powerful tool in chemical processing.

Radiation Crosslinking of High Polymers, D. J. HARMON. Paper 294A. Study made by B. F. Goodrich Co. relating to radiation vulcanization of tires; comparison of physical properties of 10 sets of chemical and radiation cures based on index of 100 for properties of chemical cures at equivalent degree of crosslinking; only natural, chloroprene, styrene-butadiene, and nitrile-butadiene rubber are included; cost considerations and new production techniques to be developed; it is concluded that unique production properties and/or process savings must exist to justify changeover to radiation process.

Suggested Code System for Low-Alloy Steels Relating Composition and Performance, R. C. RODES. Paper No. 292B. Although two steels of same composition can offer same properties, this also can be obtained with steels of different composition; causes of phenomenon; three parameters which define every steel in such way that they have same properties if parameters are same; parameters or code figures can be calculated by knowing their rate of variation with composition from which they depend; rule whereby steels can be calculated for specific applications.

NUCLEAR ENERGY

Uses of Radioisotopes in General Motors, A. SOMERVILLE. Paper No. 289A. Report on published work performed or stimulated by members of Physics Dept. of Isotope Laboratory, constructed in 1954 to explore uses and to develop economic applications of radioisotopes and nuclear techniques throughout corporation; work deals with training program, devolopment of new nuclear tools and techniques, research uses of radioisotopes, wear studies, and other development uses; quality control applications.

Equipment for High-Energy Radiation, D. A. TRAGESER. Paper No. 294B. Characteristics of following fundamental types of high energy radiation: neutrons, positive ions, X-rays and γ-rays, electrons and β-rays; important variables in accelerator design for industrial processing are energy, power, dose rate, and geometry of applied beam; elements of direct and linear accelerators; estimates of operating cost are shown in graphic form assessing future improvements.

Gas Cooled Reactors for Mobile Applications, G. G. LEETH. Paper No. 308B. Fundamental concepts of applying nuclear energy to mobile power systems; "packaged energy" approach, and nuclear power packages suitable for variety of remote environment applications; basic package consisting of "fast" reactor coupled to closed cycle gas turbine using neon gas as coolant and working fluid; coolant selection; cycle studies; specific power plant arrangement; turbomachinery and heat exchanger; applications ranging from propulsion to sea water purification, generation of electric power, etc.

MAGNETOHYDRODYNAMICS

Foundations of Engineering Magnetohydrodynamics, A. B. CAMBEL. Paper No. 312A. Definition of subject; applications of magneto-fluidmechanics: materials science, flow control, aerodynamics containment, propulsion and power generation; thermophysical properties of plasmas; essentials of electromagnetism; equations of magneto-gas dynamics; similarity considerations; experimental observations in magnetohydrodynamics and applications.

MHD Applications for Space and Ground Power, W. McILROY, A. F. KUNEN. Paper No. 312B. Propulsion devices, and Plasma Pinch Engine, under development by Republic Aviation Corp.; problems bearing on operation of magnetohydrodynamic pulsed plasma accelerators, specific impulse and energy conversion efficiency in selection of working engine; application of MHD to electrical generation for ground and space installation, and materials problems; application of magnetic field to high power thermionic converter to increase efficiency.

Some Imaginative Applications of Magnethohydrodynamics to Automotive Engineering, M. C. GOURDINE. Paper No. 312C. Feasibility of converting energy of chemical combustion into a-c electrical energy by reciprocating MHD generator; MHD motor suitable for driving one wheel of automobile; how MHD motor generator set may be used as four wheel brakes; outline of approach whereby exhaust from motor is mixed with additional air and directed through MHD afterburner, consisting of rotating radial arc in axial magnetic field.

MISCELLANEOUS

Post University On-The-Job Training for Engineers, E. J. MANGANTELLO, V. F. HLAVIN. Paper No. 314A. Summary of research activities of NASA's Lewis Research Center at Cleveland, Ohio, concerned with aerospace propulsion; efforts made with respect to educational support program are summarized giving elements in favor of program, and some of difficulties; Graduate Study Leave Act and selection of participants.

Ideas Through Pyramiding, C. W. GARDNER. Paper No. 277A. Problem solving technique called Pyramiding, is used in engineering activities of General Motors' Mfg. Development, applicable to design or manufacturing, involving discussion with group of competent people with know-how, freedom to make suggestions and to criticize; report on actual Pyramiding Session, which took place to reduce cost and improve quality of generator armature commutators.

New Ideas Through Individual Initiative, L. A. WILLIAMS. Paper No. 277B. Examples show that important ideas have come historically through individual initiative and that contribution of large industrial corporations is relatively small; reasons are discussed why large share of creative ideas will continue to come through individual initiative and not through organization; with respect to new processes it is suggested that corporations which cannot afford separate technical center consider facilities for testing in secluded area isolated from daily pressures.

SAE NEWS

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SAE LETTERS FROM READERS

From:
P. H. Schweitzer (M'23)
Schweitzer & Hussman
Engineering Office
State College, Pa.

Dear Editor:

Mr. J. S. Meurer's 1961 SAE Annual Meeting paper on multifuel engine practices (Paper No. 296A) leads me to do a bit of reminiscing.

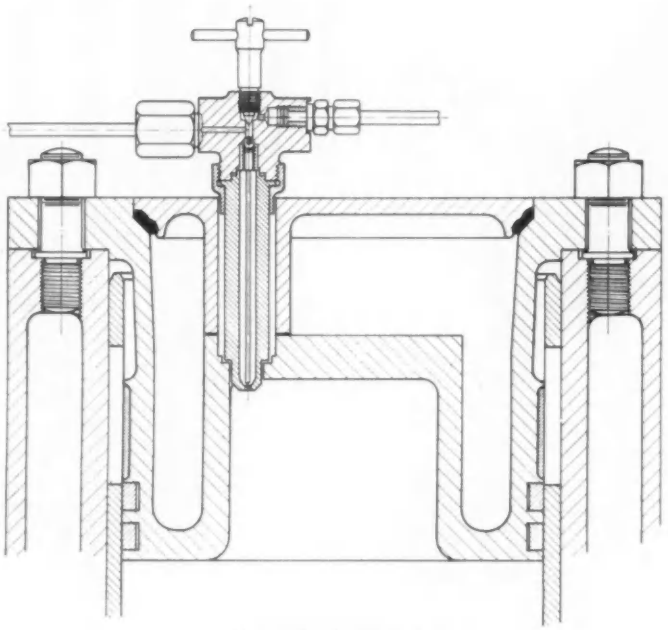
I would like to go back some 30 years when Ricardo had just discovered the diesel ignition lag, Le Mesurier and Stansfield introduced the ignition quality, and Boerlage and Broeze found a scale for it in the cetane number, except that it was cetene at that time.

We were sitting one day in the Royal Dutch Shell laboratory in Delft: Boerlage, Broeze of Shell, Horning, president of Waukesha, and myself. Horning, who, besides being a business man, was a very gifted engineer, asked the question: Is it true that fuels of the highest ignition quality have poorer fuel consumption than lower cetane fuels, and if so why? There was no disagreement on the fact but we all had different explanations. Horning himself expressed the opinion that the explosive combustion of the low cetane fuel approximates more closely the constant volume cycle, which has the highest thermal efficiency, than the high cetane fuel. Boerlage and Broeze argued that very short ignition lag makes the fuel ignite before penetrating more than a fraction of an inch into the combustion chamber. So close to the nozzle the amount of oxygen present is insufficient to burn the ignited fuel, hence smoky combustion and poor fuel consumption. The writer thought that the explosive initial combustion at the low cetane fuel produces a lot of indiscriminate turbulence which helps to burn the rest of the fuel.

Looking back we know now that all of us were wrong. Without realizing it, it was Dr. Meurer who has furnished the correct answer to Horning's paradox. If the ignition lag is very short, most of the fuel is injected into flame. Liquid fuel droplets exposed to flame temperature tend to crack. Cracking produces volatile components but also soot, i.e. solid carbon particles which burn very slowly. Hence after-burning, exhaust smoke and poor fuel consumption. All the pieces of the puzzle fall neatly in place with Meurer's concept of reaction kinetics of the combustion.

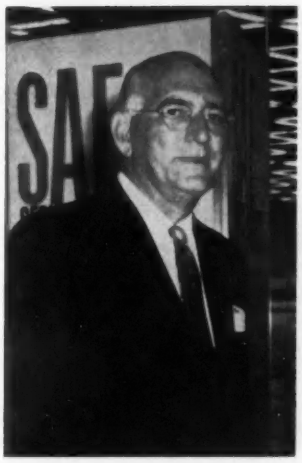
Another instance of belated explanation is found in Ricardo's discussion of Meurer's 1955 paper (SAE Transactions, 1956, p. 268). He discribes early 1923 work on a sleeve valve diesel engine (illustration at left, taken from J. H. Pitchford's 1960 SAE Paper No. 215B), with the statement that it was necessary to combine the high swirl with position of the injector axis very close to the side walls of the combustion chamber in such a way that a heavy smear of the injected fuel was deposited around the wall "downwind" of the point of injection.

Pitchford made no attempt to explain the observation but Ricardo himself frankly attributed it to the Meurer effect. "Unconsciously, then," he wrote in the cited discussion, "we were working under somewhat the same conditions as Dr. Meurer advocates." Neither did he hesitate to admit that this was a new line of thought to him: "I was brought up to believe that on no account should liquid fuel be allowed to settle on the combustion chamber wall. This new line of thought recalls, and somewhat explains, the results of our early experiments . . ." referred to in Pitchford's paper. Ricardo finally suggests that "the combustion conditions Dr. Meurer advocates are present to some much lower degree in every high-speed solid-injection diesel engine, but to Dr. Meurer and the M.A.N. Co. is due the credit for recognizing, evaluating, and cultivating them."



Sleeve valve diesel engine.

THE 3-PART CHEVROLET CORVAIR paper presented at SAE's 1960 Annual Meeting has been presented 31 times before a variety of business and technical groups since its original airing before SAE. Presentations have been made from Miami to San Francisco . . . in Columbus, Ohio; Framingham, Mass.; St. Louis, Mo.; Kansas City, Kan., and many other towns. . . . Incidentally, SAE sold four times as many copies of this Corvair paper as of the average paper — in the 12 months following presentation. (It's no longer available as a preprint through SAE.). . . . Authors of this traveled paper were K. H. Hansen, who wrote of Corvair's origin and development; F. J. Winchell, who wrote of the transmission and final drive; and R. P. Benzinger, who handled the engine.



1961
SAE President
A. A. Kucher

SAE President to Visit Europe

A THREE-WEEK visit in western Europe in May by SAE President Kucher will help solidify the constructive, informal relationships established between SAE and engineers abroad during the SAE International Congress and Exposition of Automotive Engineering in Detroit this past January.

President Kucher's itinerary will take him to automotive centers in five countries during his trip in Europe this month. Arrangements also have been completed for President Kucher to meet with members and officials of three engineering societies abroad. Plans for meetings with those of two other societies are in process.

In addition to his planned contacts with European engineering societies and their officials, President Kucher will visit a number of plants, and will confer with their executives.

President Kucher's participation in Engineering Society meetings abroad is shown in the tabulation below.

SAE members in England, France and Italy are being extended the courtesy of attending the meetings of the engineering societies of these respective countries at which President Kucher will be present. This courtesy will make it possible for SAE members in Europe to meet with their President.

All indications from abroad are that President Kucher will receive a warm welcome. Representatives from European engineering societies have indicated their eagerness to reciprocate for the hospitality extended to them during the SAE Congress in Detroit in January.

In commenting on his projected visits abroad, SAE President Kucher has said: "The SAE International Congress in January has proved to us once again the value of exchange of technical information among engineers and scientists on both sides of the Atlantic and Pacific Oceans. If my visits in Europe can be instrumental in continuing and perhaps even expanding this flow of technical information between members of our Society and those abroad, I will consider the trip a worthwhile endeavor. There is no question but that all of us have much to gain from this information interchange. Challenging developments are under way in nearly all automotive centers of the world, and the sharing of technical information will benefit technology in each country."

Mrs. Kucher will accompany the President on this trip. He will also be joined by SAE General Manager Joseph Gilbert.

President Kucher's Participation in Engineering Society Meetings Abroad

Country	Society	Date	Time	Place	President Kucher's Participation
England	The Institution of Mechanical Engineers	Thursday, May 11	5:30 p.m.	IME Meeting Hall 1 Birdcage Walk Westminster London, S.W.1, England	Address: "Automotive Engineering: Reflection and Projection"
France	Societe des Ingenieurs de l'Automobile	Tuesday, May 16	5:30 p.m.	Auditorium Chambre Syndicale of Automobile Manufacturers 2 Rue de Presbourg Paris 8, France	Guest of honor at dinner following SIA Open Meeting
Italy	Associazione Tecnica Automobile	Thursday, May 25	To be set	To be set	Guest of honor at ATA dinner

Meetings also are being planned with The Royal Aeronautical Society in London and the Verein Deutscher Ingenieure in Germany.
However, final arrangements had not been completed at the time that this issue of the SAE JOURNAL went to press.

MET SECTION

scores with "Section-Wide" sessions

350 hear 9 papers at 3 sessions.

President Kucher, Past-President Littlewood at banquet.

L. A. DOUGLASS (third from left) was general chairman for Met Section's Section-Wide Meeting at New York's Henry Hudson Hotel. Douglass is currently vice-chairman of the Section. Others prominent at the meeting were (left to right): Past Section Chairman Robert W. Hogan; Met Section Chairman Carl S. Ryan; SAE Past-President William Littlewood; SAE Past-President Leonard Raymond; and SAE President A. A. Kucher.

METROPOLITAN SECTION's "SECTION-WIDE MEETING" this year drew nearly 350 members and guests to its three simultaneous sessions and its banquet at New York's Henry Hudson Hotel on the afternoon and evening of March 9.

Nine papers at the three sessions reflected both the breadth and the depth of Metropolitan Section's technical interests. The sessions dealt with corporate and short-range jet transports; supersonic fuels, distillates, and gasolines for the '60s; and with new designs and problems of today's motor vehicles. The program for the SECTION-WIDE meeting was developed by a committee headed by Section Vice-Chairman L. A. Douglass, with whom served the Section's seven Activity vice chairmen: C. M. Rice (Aerospace), James E. Davis (Air Transport), Russell W. Meals (Diesel engines), B. H. Carpenter (Fuels and Lubricants), Robert C. Ward (Passenger Car and Body), Richard L. Courtney (Students), and George E. Kelm (Transportation and Maintenance).

SAE President A. A. Kucher was guest of honor at the meeting, and SAE Past President William Littlewood was principal speaker at the banquet.

Fanjet engines and other aerodynamic advances have now produced transports that fly about as fast as any will be able to until a new supersonic airliner is developed, said Littlewood, who is vice-president for equipment and research of American Airlines.

Scheduled flights by supersonic airliners will not begin for 12 to 15 years, Littlewood said, stressing the need to recognize that many supersonic transport problems will be quite different from those of a bomber. In the meantime, although speeds are unlikely to increase above present transsonic levels, much progress can be made in economics, reliability, and quality of performance. These factors may be improved by 30 or 40% through active research and development, Littlewood concluded.

Kucher Stresses Science-Engineering

Speaking briefly at the banquet, SAE President A. A. Kucher emphasized the marked progress which SAE has made in bringing about greater interaction and cross-fertilization between the basic applied physical sciences and product engineering.

He pointed up also SAE's activity in "going to the engineering student on the campus to bring him into intimate contact with practicing engineers." SAE, Kucher said, is bridging the gap between classroom instruction and industry practices.

"One of the most heart-warming features of SAE," President Kucher said, "is the selfless cooperation given by members to student engineers. Apparently 'student engineer' is a magic phrase, because I have yet to find an SAE member who refuses to help participate in this activity when asked, no matter how busy his schedule."

SAE National Meetings

1961

- June 5–9
  Summer Meeting, Chase-Park Plaza, St. Louis, Mo.
- August 14–17
  West Coast, Sheraton Hotel, Portland, Ore.
- September 11–14
  "Heavy Duty Vehicle"*
  (including production forum and engineering display),
  Milwaukee Auditorium, Milwaukee, Wisc.
- October 9–13
  Aerospace Engineering and Manufacturing (including engineering display), The Ambassador, Los Angeles, Calif.
- November 9–10
  Fuels and Lubricants, Shamrock Hotel, Houston, Texas

1962

- January 8–12
  Annual (including engineering display), Cobo Hall, Detroit, Mich.
- March 12–16
  Automobile Week (combined National Automobile and Production Meetings), Sheraton-Cadillac, Detroit, Mich.
- April 3–6
  Aeronautic (including production forum and engineering display), Hotel Commodore, New York, N.Y.
- June 11–15
  Summer, Chalfonte-Haddon Hall, Atlantic City, N. J.

* Combined Farm, Construction and Industrial Machinery; Powerplant; and Transportation Meetings

Rambling through

THE REAL "CHALLENGE OF INDIVIDUALISM," — said Chrysler's Vice-President and SAE Past-President H. E. Chesebrough at **MONTREAL SECTION'S 10TH ANNIVERSARY** meeting recently — arrives when man feels engulfed by scientific developments . . . when machines appear overwhelming . . . and when the way of life he has helped to create seems beyond his control. At this challenging point, Chesebrough said, it's good to remember "what man has the ingenuity to make, he has power to control, modify, or reorganize . . . even while he continues to invent."

As 5-point guidance for young engineers in the audience, Chesebrough suggested they:

- Learn to think as individuals — though working in groups.
- Be openminded — keeping a "weather eye" out for the new.
- Listen to the other fellow — it fosters understanding.
- Be practical — remembering that the new product has to face competition profitwise.
- . . . And lastly . . . "Know yourself — but don't overdo it."

SAE Past-President H. E. Chesebrough, (left) talks with MONTREAL SECTION Chairman B. H. Miller (right) at the Section's 10th Anniversary Meeting.

TURBOPROP-SUPERCHARGED, streamlined-aircraft-type-fuselaged Ford Levacars — supported by frictionless "ball bearings" of air — guided by a network of rail lines . . . was the not-too-far-off transportation possibility dealt with by SAE President A. A. Kucher in his talk before **ONTARIO SECTION'S** February meeting.

AND AT SOUTHERN **NEW ENGLAND SECTION'S** Silver Anniversary Meeting in February — where SAE President A. A. Kucher was guest speaker — a working model of the Levacar was displayed to the Section meeting audience. Hosted also at this Silver Anniversary Meeting were 1957 SAE President W. Paul Eddy; John G. Perrin, who joined the Society in 1905; SAE Secretary and General Manager Joseph Gilbert; and two members who received 25-yr membership certificates — Charles W. Phelps and Richard A. Valentine.

Inspecting the working model of Ford's Levacar presented at SOUTHERN NEW ENGLAND SECTION'S Silver Anniversary Meeting are (starting left) SAE Past-President W. Paul Eddy; SAE President A. A. Kucher; Section Chairman Arnold D. Nichols; and SAE Secretary and General Manager Joseph Gilbert.

IN A WIDELY DISPERSED FLEET — with equipment away from home base sometimes for two months — major repair is a big problem. . . . But experience has shown that the odd engine or other major assembly which has gotten "out of kilter," usually makes it to home base, and survives for continuing service. So, the rule "Bring them home for major repair — even if they have to be carried" is a good one, according to Gordon C. Carr when addressing Ontario Section's March meeting. Carr is mechanical manager of Tippet-Richardson, Ltd., and president of the Automotive Transporation Service Superintendents Association.

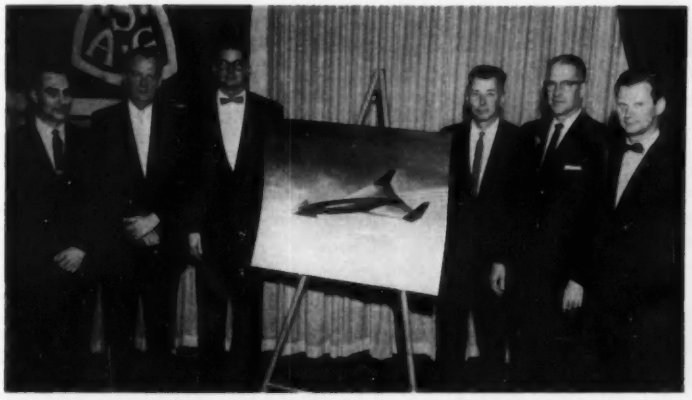
SMALL AIRPORTS — placed close to towns and cities to reduce ground travel time and open up many new areas to air transportation — could be of low-cost, simple strip type . . . yet adequate for light aircraft. This was the theme of Piper Aircraft Corp.'s President, William T. Piper in his talk before **WICHITA SECTION'S** February meeting.

NEVER ARE EUROPEAN CARS likely to compete with American cars in the United States strictly on price, says **Henry L. Brownback.** The lower direct labor costs abroad are offset by import duties, high costs of transportation and preparation for ocean shipping, according to the internationally-experienced engineering consultant. "Besides," **PITTSBURGH SECTION** Field Editor R. F. Mather reports Brownback as adding, "servicing problems of European cars are inherently greater in the U.S. To achieve substantial American volume, a European car has to have all-around attractiveness, plus some outstanding feature of luxury, finish, or operating economy."

the Sections

THAT A MACH 3 TRANSPORT — with an expected life of about 30,000 hr — is now technically and economically feasible . . . was the conclusion of a 5-man panel at **SAN DIEGO SECTION'S** February meeting (held jointly with the Institute of Aeronautical Sciences). Some other points of the panel agreement were:

- Weight of the aircraft would be about one-third-million pound gross takeoff — 50 or 60% of which would be fuel.
- Flight outer surface temperatures would approach 500 deg.
- The fuel itself would be used as a heat square.
- The airconditioning system would maintain passenger areas at 70 deg.
- With a cruise altitude of about 70,000 ft, the sonic boom and aerodynamic noise problems would be greatly diminished — although fatigue failure due to sonic resonance might become a problem.



Centered around a projection of a Mach 3 Transport — topic of a 5-man panel discussion at SAN DIEGO SECTION'S February meeting — are (starting left) General Electric's J. I. Hope; Rohr's H. M. Rush; Ryan's L. S. Reel; Convair's W. H. Schaeffer; Solar's W. C. Benson — with Convair's C. L. Blake, who was discussion leader.

Featured at SAN DIEGO SECTION'S booth during National Engineers' Week in Balboa Park was the Ryan Q-2C Firebee. Chairman of SAE's exhibit was Ryan's Burt Winslow (right); with Section Treasurer Floyd Rechlin of Narmco (left); and Ryan's Richard L. Kimble (center). The booth was manned throughout the week by Section members.

CONTAINERIZATION — combined with the truck train — could help shape the trucks we'll be seeing on the 1975 super highway system . . . International Harvester's Chief Engineer John C. Wagner told **CLEVELAND SECTION'S** March meeting audience.

Edward D. Crocker, trial attorney, — and coffee speaker at the meeting — talking on "Current Trends in Product Liability," cited various lawsuits against manufacturers, basis for claims, and liability involved. Today, Crocker said, the manufacturer is responsible and liable for his own negligence — even though the sales contract was between a retailer and his consumer customer. . . . And in talking on warranty claims — the second phase of liability — Crocker said that in accident or product failure, lawyers have a tendency to get right into the manufacturing plant to investigate materials and methods to detect weaknesses.

HYSTERETIC LOSSES of a rubber determine its frictional resistance in sliding over surfaces, says C. W. Umland II, Enjay Laboratories' senior chemist in accounting for the exceptional braking traction of butyl rubber. Umland's talk before the February **SOUTH TEXAS GROUP** meeting brought out the many uses for this rubber in transport applications.

THE ION-EXCHANGE MEMBRANE CELL — using gaseous hydrocarbons or liquid alcohol for fuel — is a "tomorrow possibility". . . according to Autolite's Director of Chemical Research, Dr. Manuel Shaw. But great strides must first be made to improve its power output and service life, he said in his talk on "A Realistic Look at Fuel Cells Today" at **TWIN CITY SECTION'S** February meeting.

A WIDE RANGE OF FUELS — from JP 4, JP 1, jet and diesel to kerosene and stove oil — can be used in Boeing's light weight 250 hp Model 502 gas turbine. This was one of the facts brought out by Boeing's George Cashman when talking on "Development of a Small Gas Turbine" before the February meeting of **BRITISH COLUMBIA SECTION.**

Rambling through the Sections

THE BRAIN OF TASI — Bell Telephone Laboratories' "Time Assignment Speech Interpolater" — uses the pulse and digital techniques of modern computers. By disconnecting talkers who are momentarily silent in transoceanic submarine cable conversations, it takes advantage of idle periods to connect more talkers to channels than there are full-time channels available. Hawaiian Telephone Co. has the third such installation in existence . . . and its telephone engineer, Robert H. Smith told **HAWAII SECTION** all about it at the Section's February meeting. A number of Section members saw TASI in operation at the telephone company headquarters after the meeting.

Hawaiian Telephone Co.'s Engineer, Robert H. Smith (left) shakes hands with HAWAII SECTION Chairman Morito Tsutsumi at the Section's February meeting.

AS FERTILE FIELDS FOR RESEARCH in smog removal, Stanford Research Institute's Prof. Dale Hutchinson suggests: finding means for removal of organic contaminants from the atmosphere; investigation of influences of sulfur and nitrogen oxides; and health hazards resulting from air pollution. He said further, in his talk before **NORTHERN CALIFORNIA SECTION'S** March meeting, that the problem is not industry's alone — the public must clean up, too.

Air Pollution Control District's Chief Enforcement Officer Joseph Coons told the Section that probably the best control over incineration (one major pollution cause) would be abandonment of small burning operations for better-designed, large-scale units.

MAINTAINING THE TRUCK MAINTENANCE MANAGER was the subject of ATA's Automotive Engineering Section Chief Lewis C. Kibbee (left) before **NORTHWEST SECTION'S** Annual Meeting in Tacoma on March 3. Knowing the latest engineering developments and showing management how they can be applied is a responsibility of the maintenance manager, said Kibbee, who is also an SAE Director. Ed. Baldwin (right), Washington Motor Transport Association, gave a summary of the local Association's functions. In the center is Lewis W. Schroeder, Northwest Section chairman . . .

a n d

. . . talking earlier before **SALT LAKE GROUP'S** February meeting, SAE Director Kibbee stressed the need for some idea-recasting by management to meet maintenance requirements because of radical changes in truck design required by the new highway system.

ECONOMICAL, ELECTRICALLY HEATED GLASS, and electro-luminescent glass panels are among the long-range objectives for compact and larger cars . . . Russell G. Whittemore, Pittsburgh Plate Glass Co.'s director of product development told Pittsburgh Section recently. Among the "forecasts" he cited use of larger glass areas; more heat absorbing (tinted) glass; curved sidelights; and continuing use of windshields and backlights.

Indications are that liners may soon be eliminated in aluminum automobile engines . . . Richard M. Smith, Aluminum Co. of America's Development Division engineer reported at the same meeting. This would come about, he said, through the use of high-silicon aluminum casting alloys and chrome plated pistons to prevent seizing and scuffing during cold starts.

A 250,000 MILE TRUCK is the objective, according to Ford's Truck Engine & Electrical Department Manager, Gale R. Beardsley when talking before INDIANA SECTION'S February meeting. . . . But accelerated controlled engineering tests and customer fleet evaluation must provide necessary data for engineering certification. His discussion of salient design actions and test programs involved in the objectives of Ford's new "H" series is contained in SAE Preprint S295.

...continued

A GUIDED TOUR of Norad Control Center's Missile Master at Fort Lawton — arranged for by W. C. Tarbet, Jr., and conducted by 26th Artillery Group Commander, Colonel Pixton — Comprised **NORTHWEST SECTION'S** February meeting.

One of the many points of interest to the 62 members who participated was a demonstration of what happens when an unidentified object is picked up on radar.

■

Articles in this issue based on Section presentations . . .

- **Detroit Section**

  "Space-Probing Workhorse" is Saturn's Destiny ..... p 74
  — Dr. Wernher von Braun

- **Detroit Section — Junior Activity**

  "Hurricane Road" Cures Many Auto Woes ..... p. 76
  — Charles A. Freeman, Jr.
  William G. Cato and Jerome Meek
  Thomas E. Dreaver and Edward L. Richardson

- **Metropolitan Section**

  Step by Step to the Moon ..... p. 91
  — Col. Donald H. Heaton

S A E Section Meetings

ATLANTA SECTION

May 1 . . . Joseph M. Stout, Lincoln Continental engine engineer, Ford Motor Co., "The 1961 Lincoln Continental Engine — A New Concept of Power Plant Reliability." Cocktails 6:30 p.m. Dinner 7:00 p.m. Meeting 8:00 p.m.

BALTIMORE

May 11 . . . Robert Tates, mathematician, Advanced Concepts Division, The Martin Co. "Rockets & Space Vehicles." The Martin Co., Middle River, Md. Dinner 7:00 p.m. Meeting 8:00 p.m.

CENTRAL ILLINOIS

May 22 . . . John A. Kilborn, Kilborn Motor, Inc., "Sports Car Racing." Gus T. Greenias, attorney, former judge of Macon County Court "Light Legal Chatter." Decatur Club, 158 W. Prairie St. Decatur, Ill. Dinner 6:30 p.m. Meeting 7.45 p.m.

FORT WAYNE

May 10 . . . B. L. Douglass, district manager, Hydrostatic Transmission, Sundstrand Aviation "Hydrostatic Transmissions for Vehicle Propulsion." Hobby Ranch House, corner of Crescent & Anthony Avenues. Dinner 6:30 p.m. Meeting 8:00 p.m.

ROCKFORD-BELOIT

May 1 & 2 . . . "Machine Tool Conference." Will include several papers, panel discussion and plant tour. Wagon Wheel Lodge, Rockton, Ill. Dinner 6:30 p.m.

ST. LOUIS

May 9 . . . "Diesel Engine Activity Meeting." Congress Hotel, St. Louis, Mo. Dinner 7:00 p.m. Meeting 8:00 p.m.

SOUTHERN NEW ENGLAND

May 17 . . . Social Meeting, Farmington Country Club, Farmington, Conn. Dinner — dance.

SYRACUSE

May 12 . . . Dr. T. A. Boyd. "Education." Statler Inn, Ithaca, New York. Dinner 6:30 p.m. Meeting 7:30 p.m.

TEXAS

May 12 . . . Dr. Willis Tate, president, Southern Methodist University, Dallas, Texas. "Engineering Education." Social 6:30 p.m. Brookhaven Country Club, Dallas, Texas. Dinner 7:30 p.m. Meeting 8:30 p.m. Special feature: Ladies Night; also a short film, "Man and the Moon."

WILLIAMSPORT

May 1 . . . Eugene D. Lavery, supervisor, Customer Information, Bell Telephone Co. "Project Echo." Moose Hall, Williamsport, Pa. Dinner 6:45 p.m. Meeting 8:00 p.m.

HEADING THE GENERAL COMMITTEE of the meeting were H. D. Hall (left) and C. C. Dybvig (right).

"BREAKTHROUGHS" Highlight SAE National Automobile Week

EXTREMELY POPULAR at SAE's National Automobile Week Meeting in Detroit were technical papers on "breakthroughs" in car assembly, driver behavior, bonding techniques, drivelines, molded parts for body interiors, and steels for tomorrow's automobiles.

B.O.P. Assembly Plant

GM's B.O.P. South Gate Plant in California represents a breakthrough in assembly operations. It uses a single line system to assemble Buick, Oldsmobile, and Pontiac passenger cars as well as the new Buick Special, Oldsmobile F-85, and Pontiac Tempest. It can best be described as a Fisher Body assembly plant combined under one roof with a motor car assembly plant — multiplied by six. The operation has one plant manager and one set of all necessary productive and nonproductive departments.

Driver Behavior

Experienced automobile drivers use the brakes less often, make fewer speed changes, and can travel a given route in less time than inexperienced drivers. These were preliminary findings in a research project now being carried out by Ford, in which driver behavior is being studied by applying the mathematical techniques of operations research. The driver's behavior is studied in relation to highway and traffic situations which he is likely to face. The various situations are measured for their relative influence on the driver.

In one aspect of the study, results seem to indicate that most drivers maintain a certain constant rhythm of actions — adjusting the accelerator and steering — no matter whether they are driving in heavy or light traffic, or in the city or in the country. Also, it was found that the more experienced driver makes just about as many changes in steering as in speed; while the less experienced driver makes far more corrections in steering than in speed. The total number of reactions remains nearly the same.

From the study, Ford hopes to obtain new information about how different kinds of vehicles, equipment, and environments affect driver reactions. This information will be helpful in developing new driver education techniques and in evaluating traffic flow theories.

Bonding Techniques

High strength, organic polymer adhesives, such as epoxies and phenolics, are being used successfully as a bonding for solid fuel rocket motor cases which undergo stresses up to 250,000 psi. One adhesive, designed so that its shear modulus varies along a bonded joint, withstands 25% higher loads than one with a constant shear modulus. This new adhesive was able to withstand up to 3900 psi on a six-inch overlap seam; whereas the best available conventional adhesives failed at 3100 psi.

It is predicted that similar adhesives will enable designers to create hardware previously thought impossible. Design safety factors will be based on metal ultimate allowables instead of yield allowables, and thereby result in significant weight reduction. Dissimilar metals will be joined in compound structures at lower cost. Also, large prototype structures will be made without the need for the costly and complicated tooling that is required for conventional joining methods.

New Drivelines

The 1961 model year, especially with the advent of compact cars, has resulted in several unusual approaches to the driveline design.

One of these, the Lincoln Continental driveshaft assembly, incorporates

AT WEDNESDAY'S LUNCHEON: (left-to-right) M. M. Roensch, Elmer Bernitt, James O. Wright, and Dr. A. A. Kucher.

Wright, guest speaker at the luncheon, spoke on The Relationship of Product Planning to Engineering. Bernitt was toastmaster at the luncheon. Dr. Kucher is 1961 SAE President. Roensch is SAE Detroit Section Chairman.

the low friction recirculating roller bearing spline, a rubber element for axle gear noise suppression, a constant velocity double Cardon universal joint for high angular operation, and a forged end yoke for tunnel clearance.

Technical papers on the 1961 Tempest driveline and Buick's low-profile driveline, equally interesting and unusual, also were presented at the meeting.

Molded Parts

Molded parts are being used increasingly in automobile interiors. Typical of these is the molded fiberglass headliner.

A layer of "uncured" fiberglass insulation (approximately 80% glass, sprayed with 20% phenolic resin by weight), a layer of polyethylene film, and a layer of fiberglass decorative trim fibric, frame loaded, are placed between heated molds. With the closing of the press under heat and pressure, the phenolic binder cures and the combination of resin and glass fibers permanently take the "set" of the molds. Also, the polyethylene becomes the thermoplastic mechanical bond between the trim fabric and the insulation pad.

The part is the moved to the trim fixture, where it is trimmed to the final size, and holes for the domelight, sun visors, and coat hooks are punched. It is inspected and placed in corrugated cartons for shipment to the automobile assembly plant.

High-Strength Steels

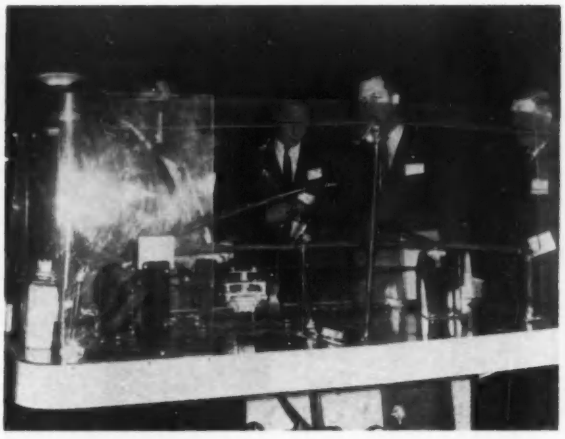
A large family of structural steels with yield points varying from 30,000–100,000 psi is presently available to

CHAIRMEN OF PARTICIPATING ACTIVITIES—top: (left) T. H. Thomas, Passenger Car (right) K. O. Tech, Production; bottom: (left) A. H. Smith, Production (right) D. C. Perkins, Body.

SAE PAST-PRESIDENTS in attendance at Wednesday's luncheon were: (left-to-right) C. A. Delaney, Harry Chesebrough, Dale Roeder, and Leonard Raymond.

TOASTMASTER at Thursday's luncheon was C. F. Nixon, GMC.

GUEST SPEAKER at Thursday's luncheon was Dr. R. J. Lund, assistant technical director of Battelle Memorial Institute. Lund spoke on The 10-Year Outlook for Metals.



SAE MEMBERS INSPECT 1961 Lincoln hydraulic windshield wiper — part of a display on power-operated body mechanisms.

OVERFLOW CROWD attended "Engine Workshop" session on piston rings and cylinder bores.

DETROIT-AREA HIGH SCHOOL STUDENTS and their teachers sat in on technical sessions and attended luncheon at the meeting. M. M. Roensch, SAE Detroit Section chairman, answered their questions at afterglow session. High schools represented were Edsel Ford, Catholic Central, Seaholm, Denby, and Cass Technical.

Automobile Week ... continued

automotive designers. Because the per cent increase in price of higher strength steels (compared to the price of carbon steel) is smaller than the per cent increase in yield point, the application of higher strength steels results in lighter weight structures that in many cases show substantial material-cost savings. Cold-formed light-gage beams show weight savings up to 67% and material-cost savings up to 29%.

Panel Sessions

Well-attended panel sessions were held on: Steering and Suspension Joints Requiring No Service Lubrication; How Much Paper Work is Really Necessary?; Better Communications Between Product Engineering and Manufacturing; Equipment Replacement Pointers; High Energy Forming Processes; Unique Manufacturing Processes; and, What Happens to a Gear During Grinding?

An all-day discussion of engineering problems involved in the design, material selection, and operation of piston rings and bores was presented under the title Some Questions and Answers About Engine Wear and Other Problems. Members of the Engine Subcommittee of the SAE Passenger Car Activity were on hand to participate in the discussion and to answer questions from the audience.

Luncheons

Two luncheons were held as part of the meeting. At the Wednesday luncheon, James O. Wright, vice president and group executive — car and truck group, Ford Motor Co. was the featured speaker. Wright discussed the relationship of product planning to engineering. Elmer W. Bernitt, vice president of operations, automotive division, American Motors Corp. was toastmaster at the luncheon.

At the Thursday luncheon, Dr. R. J. Lund, assistant technical director of Battelle Memorial Institute, spoke on The 10-Year Outlook for Metals. C. F. Nixon, head, electro chemistry and polymers dept., research laboratories, GMC, was toastmaster.

The SAE Detroit Section served as host for the SAE National Automobile Week Meeting. M. M. Roensch is chairman of SAE Detroit Section.

Activities for the week were under the direction of a General Committee headed by C. C. Dybvig and H. D. Hall.

Participating Activities at the meeting were: Body — D. C. Perkins, chairman; Engineering Materials — A. H. Smith, chairman; Passenger Car — T. H. Thomas, chairman; and, Production — K. O. Tech, chairman.

SAE MEMBERS

Preble

T. L. PREBLE is currently automotive consultant to the Budget Bureau of the City of New York. He is playing an important part in the Bureau's efforts to unify and coordinate the operating, maintenance, and purchasing policies of the City's fleet of more than 10,000 vehicles of all kinds. Preble, who is also a vice-president of Ross & Co., is a past SAE Director and a past-chairman of the SAE Metropolitan Section.

Frey

DR. DONALD N. FREY has been appointed product planning manager, Ford Division of Ford Motor Co. Frey was formerly assistant chief engineer, Ford and Mercury product engineering office.

Moore

CHARLES C. "DINTY" MOORE was honored recently by 70 of his associates when they gathered at a retirement dinner celebrating 40 years of service in petroleum research with Union Oil Co. of Calif.

Moore served on SAE Fuels and Lubricants Activity Committee, SAE Fuels and Lubricants Technical Committee and was active in many committees in the CRC.

During World War II he served on the National Aviation Advisory Board and in 1954 was appointed the National Advisory Committee for Aeronautics.

Marshall

THOMAS J. MARSHALL has been appointed to a new corporate staff position, director of market research and planning of Federal-Mogul-Bower Bearings, Inc. Marshall was formerly sales manager of the Federal-Mogul Division.

Botnick

MAURICE M. BOTNICK, formerly general sales manager, has been elected vice-president-sales, of Silent Hoist & Crane Co.

WILLIAM SWALLOW has been appointed managing director of Vauxhall Motors, Ltd., a General Motors subsidiary. Swallow was formerly managing director and chairman of the board of directors of General Motors, Ltd., another GM subsidiary.

DONALD E. KIEFERT has been appointed chief engineer at the Otto Biefeld Corp. Kiefert was formerly chief design engineer for the Investment Casting Division, Howard Foundry Co.

GEORGE J. SCRANTON has been named chief, mechanical engineering. He is also associated with the Hawaiiana Hotel as vice-president and Tropicopters, Inc. as vice-president. He was formerly coordinator, Air Force Research & Development for Ford Motor Co.

WILLIAM C. HEATH has been appointed chief of technical services for Cosmic Corp. Heath was formerly manager industrial products for Solar Aircraft Co.

Heath was vice-president of SAE, 1959, member of Aircraft, Aircraft Powerplant and Air Transport Activity Commitees. He was also a member of CEP Committee.

D. STUART BLACKMORE has been appointed coordinator of administrative methods and planning for The British American Oil Co., Ltd. He was formerly national supervisor, industry and transportation.

HUDSON T. MORTON has been appointed quality control manager and chief metallurgist at Industrial Tectonics, Inc. Morton was formerly assistant factory manager and chief metallurgist for the same company.

J. B. KELLEY is now president of Die Casters' Services, Inc., a new Ohio corporation, chartered for the purpose of manufacturing and supplying expendable parts and materials to the zinc and aluminum die casting industry in the domestic and foreign market areas. Kelley had been president of the Pneumatic Power Equipment Corp.

Kelley

Mackay

RALPH M. LEHMAN has been made general manager of the Lafayette Division of Ross Gear and Tool Co., Inc. Formerly, he was general sales manager of the corporation.

ROBERT W. MACKAY has been named chief project engineer at the Bay City plant of The Electric Autolite Co. He was formerly chief engineer for generators at Autolite.

RAYMOND I. BIRKHOLZ has been appointed staff engineer for foreign operations, Engineering Department, International Harvester Co. He was formerly assistant division chief engineer, product engineering group tractors for the company.

LEWIS C. KIBBEE, director, engineering department, American Trucking Associations, Inc. was a panel participant at the first Institute of Motor Transportation Management held last April by the School of Business Administration of The American University of Washington, D. C. Kibbee is currently an SAE Director.

B. D. COLLISON has been appointed senior design engineer for Military & Civilian Products. Collison was formerly operations analysis for McDonnell Aircraft Corp.

HERBERT L. FORMAN has become filter development engineer for Pall Corp. He formerly served Purolator Products, Inc. as engineer in charge of laboratories.

ANTON O. MELBY, who formerly served E. I. duPont de Nemours & Co., Inc. as technical manager, petroleum chemicals, western region, has been appointed head, Orchem Market Development Division for the company.

CHARLES HOLLERITH has become chairman of the board and treasurer of Hollerith-Eaton, Inc. He was formerly president and treasurer of the company.

ANGELO R. DeVITO, formerly project engineer for the Atwood Vacuum Machine Co., has become consulting engineer for Atwood.

R. W. HOWELL, formerly vice-president Equipment Steel Product Division, Union Asbestos & Rubber Co., has been appointed superintendent — mobile products, Vickers, Inc., Division of Sperry Rand Corp.

Lehman

Birkholz

LLOYD A. HASSELL, formerly assistant plant manager has been appointed manager, automotive manufacturers' sales division of Electric Storage Battery Co. (Canada) Ltd.

ROBERT R. BEACHLER, JR., has been elected vice-president of the Leach Corp. Beachler formerly served Leach as corporate director of engineering.

Beachler is a member of SAE Shock and Vibration Committee.

JOHN R. COLGAN, formerly master draftsman at Westinghouse Electric Corp., has been appointed designer for the Astronuclear Laboratory, Westinghouse Electric Corp.

RICHARD F. SHUGERT has been named senior staff project engineer for the Autonetics Division, North American Aviation, Inc. Shugert formerly served as chief industrial engineer for Thermoid Division, H. K. Porter, Inc.

F. W. KELSEY has been named manager, manufacturing services section for Chrysler Corp.'s Missile Division. He was formerly manager of production, Engineering Missile Division, Chrysler Corp.

A. G. LAAS, formerly quality control manager for Westinghouse AGT Division, has been appointed reliability engineer for the Warner Gear Division, Borg-Warner Corp. Laas is a member of SAE Surface Finish Committee.

RALPH J. RASMUSSEN has been named project engineer for Formsprag Co.'s line of Rev-Lok dual torque-locking and positioning devices. Rasmussen was formerly associated in a research and development engineering capacity with Dana Corp.

DONALD S. FRASER has been appointed staff petroleum product engineer at Gulf Research & Development Co. Fraser was formerly foreign product coordinator. for Gulf.

LEONARD E. MOODY has been appointed director, Chemicals Research Division, Esso Research and Engineering Co. He was formerly assistant manager of research for Humble Oil & Refining Co.

EDWARD C. SINTZ has been appointed assistant staff engineer product engineering department of the Cadillac Motor Car Division, GMC. He was formerly assistant staff engineer in the engine department at Cadillac.

JOHN B. RICHARDSON replaces Sintz as assistant staff engineer in the engine department. He was formerly a senior research engineer in the laboratory at Cadillac.

M. G. BEKKER has been appointed head, land mobility laboratory, Defense Systems Division, GMC. He was formerly chief, land locomotion laboratory, Ordnance Tank — Automotive Command.

GERALD DUANE FOSTER has been named assistant project manager for the Utah Division, Thiokol Chemical Corp. Foster formerly served as field service representative for Rocketdyne, Division of North American Aviation Corp.

ARTHUR D. WALKER has been appointed general manager, glass fabricating operations for Ford Motor Co. of Canada, Ltd. He was formerly manufacturing manager, glass fabricating operations at the same company.

FILIBERTO VARGAS has become design engineer for the Boulder Division of Beech Aircraft Corp. Vargas formerly served the Rocketdyne Division, North American Aviation, Inc. as research engineer.

EVERETT G. HARVEY has been appointed senior product engineer — hose for B. F. Goodrich Industrial Products Co., He was formerly sales engineer for the Quaker Thermoid Division, H. K. Porter Co., Inc.

WAGN TRAUTNER has become head of products development engineering for Peterson Mfg. Co. He was formerly chief engineer for Grote Mfg. Co.

HOWARD D. BROWN has become consultant for Highway Trailer Co. and General Machine Products Co. He was formerly engineer for American Telephone & Telegraph Co.

PHIL ADOLF has been named assistant vice-president, sales engineering for Georg Schaefer Kugelfischer. He was formerly chief project engineer for Diesel Energy Corp.

DAVID C. RILEY has been appointed mechanical engineer for Johnson & Johnson, Ltd. He was formerly college apprentice for A. E. I. (Manchester) Ltd.

FRANCIS ESHLEMAN has been appointed project manager, field services for the Thiokol Chemical Corp. He was formerly field service engineer, Rocketdyne Division, North American Aviation, Inc.

HARRY A. DOZIER has been appointed sales engineer for Williams Power Brake Equipment Co. Dozier formerly served as assistant to vice-president at Consolidated Freightways.

LLOYD E. WILLIAMS has been appointed raw materials manager for Container Corp. of America. He was formerly vice-president at Pioneer Paper Stock Co., Subsidiary, Container Corp.

A. FRANK CAMPBELL, formerly advanced manufacturing engineer for General Electric Co., is on special project assignment for GE.

GERALD J. SCHMIDT, formerly structures test engineer for McDonnell Aircraft Corp., has been named structures test engineer at the Martin Co.

LARRY W. NOGGLE has been appointed powerplant research engineer for Wright-Patterson Air Force Base, Ohio. He was formerly research engineer for the Allison Division, GMC.

DONALD G. FRAKES has become reliability engineer for Buick Motor Division, GMC. He was formerly project engineer at General Motors Proving Ground.

WILBUR W. JARVIS, JR. has been named heating and air conditioning engineer for Wilbur Jarvis & Son. He was for junior engineer for the AC Sparkplug Division, GMC.

THOMAS M. SULLIVAN, formerly West Coast manager for Fairchild Engine and Airplane Corp., has become program manager for Thompson-Ramo-Wooldridge, Inc.

RONALD LYONS, JR. has become industrial engineer, senior material processes for Lockheed Missile and Space Division, Lockheed Aircraft Corp. He formerly served Lockheed as functional test engineer.

JOHN R. WALTERS has been appointed president of Tentronics Corp. He was formerly manager, Avionics Division, Calbest Electronics.

RENE C. McPHERSON has been elected to the office of president of Hayes Steel Products, Ltd., an affiliate of Dana Corp. He was formerly executive vice-president of Hayes.

DALE E. BOUGH has been appointed sales manager of the Lafayette Division. He was formerly sales engineer for Ross Gear and Tool Co., Inc.

J. P. BUTTERFIELD has been appointed executive engineer for The Martin Co. Butterfield formerly served Chrysler Corp. as director, Advanced Projects Organization.

ROBERT L. PONS, formerly project aerodynamics engineer for the Defense Systems Division, GMC, has been appointed senior staff member, space systems for the Aeronutronic Division of Ford Motor Co.

CHESTER D. CHRISTIE, formerly sales manager — axles at Eaton Mfg. Co., has been appointed assistant general manager for Eaton.

A. J. JUNKER, formerly chassis engineer, quality control department, Ford Motor Co., has been appointed chief quality engineer, automotive engineering staff, American Motors Corp.

STEPHEN J. O'BRIEN has been appointed sales engineer — marine for Standard Oil Co. of Calif. O'Brien formerly served Standard Oil as sales engineer.

THEODORE M. GREEN has been appointed sales engineer for Redmond Co., Inc. Green formerly served Redmond Motors, Ltd. of Canada as vice-president.

LEO J. HOPFENSPERGER has been named project engineer for the Marion Power Shovel Co. He was formerly design engineer at Northwest Engineering.

KENNETH A. STONEX, GM Proving Grounds' assistant director, is Highway Research Board Award winner for his paper "Roadside Design for Safety." Out of more than 200 submitted to its January 1960 annual meeting, the Stonex paper was selected by the Board as "the technical paper of outstanding merit for the year."

. . . And at the 47th Annual Purdue Road School on March 28, Stonex is presenting his "Scientific Highway Design for Safer Motoring" paper, which is essentially the one he gave at SAE Detroit Section's Greenbrier meeting last September.

Obituaries

K. W. BIRKIN . . . (M'24) . . . manager, motor vehicle department, Sinclair Refining Co. . . . died January 8 . . . born 1895.

WALTER L. DIXON . . . (M'25) . . . president and construction engineer, Dixon Marine Industrial Power Transmission, Inc. . . . died December 31 . . . born 1890.

JAMES GREENLEE . . . (M'15) . . . retired vice-president and director, Imperial Brass Mfg. Co. . . . chairman of SAE Chicago Section 1944–45. Gave inspired service to the Section in many capacities over many years and was a prominent figure at SAE national gatherings . . . died January 17 . . . born 1892.

WARREN B. HASTINGS . . . (M'21) . . . former general manager, Ontario Motor League. Ontario Section Chairman in 1948–49, and Secretary over a long period of years during which he contributed vastly and effectively to the Society's prestige, welfare, and progress. . . . For many years editor of "Canadian Motorist" . . . died February 9 . . . born 1890.

OSWIN HAUCKE . . . (M'28) . . . owner, Chass-o-Meter Co. . . . died January 13 . . . born 1886.

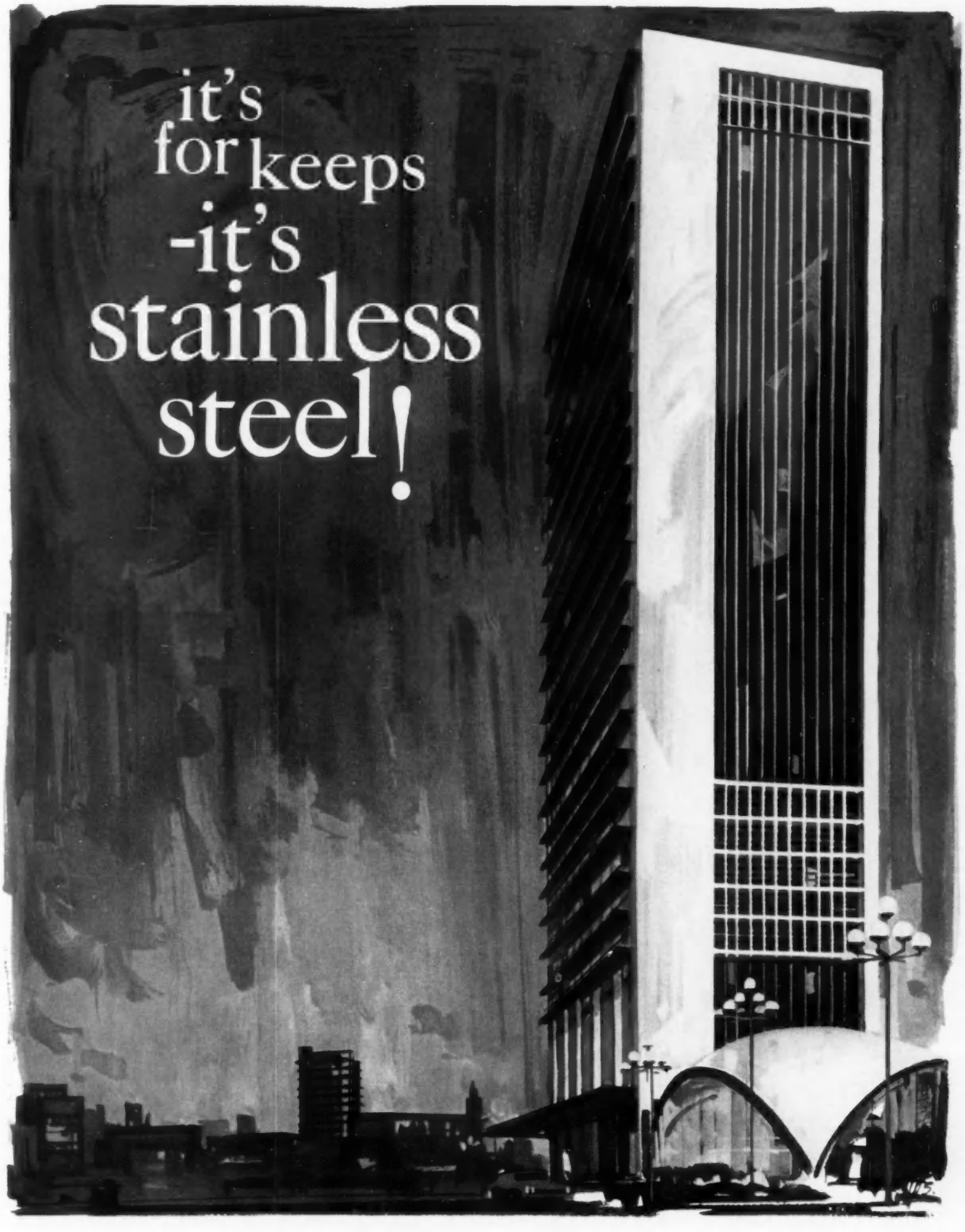
ALBERT S. HOLZWASSER . . . (M'37) . . . president, treasurer, Arrow Armatures Co. . . . died January 17 . . . born 1897.

PAUL PIGOTT . . . (M'51) . . . president, Pacific Car & Foundry Co. . . . died January 23 . . . born 1900.

HAROLD G. RAHN . . . (M'53) . . . sales manager, Pacific GMC, Ltd. . . . died December 24 . . . born 1921.

JOHN M. RIORDAN . . . (M'51) . . . president, Riordan Machinery Co. . . . died January 23 . . . born 1884.

EDWARD W. STOCK . . . (M'25) . . . retired . . . died January 16 . . . born 1891.



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Continued from page 104

differences in the intrinsic ignition resistance of fuels may be more apparent in the presence of deposits accumulated in place than with deposits aspirated into the combustion chamber.

The mean time occurence of peak pressure is influenced primarily by deposit volume and thermal effects. Thus, it may not be a suitable measure of surface-ignition activity.

Surface-ignition rankings of fuels based on peak pressure time measurements are best defined by an examination of the earliest times of peak pressure.

■ **To Order Paper No. 293E . . .**
from which material for this article was drawn, see p. 6.

Man Returns Spacecraft to Earth

Based on paper by

MAX I. BEERS, CARL C. STOTZ, and RICHARD A. WALLACE
Sperry Phoenix Co.

THE MAN System (Microwave Aerospace Navigation) is a completely integrated system for guiding hypersonic space vehicles to a landing on earth.

With ground control equipment at the landing site and data transponder equipment aboard the vehicle, this system will control the re-entry, approach, and landing of a manned or unmanned spacecraft. It performs all the major functions required to guide an aerodynamic re-entry glider, such as the Dyna Soar, to a safe return to earth. These functions are:

- Location of position and measurement of velocity of the vehicle.
- Transmission of command data to the vehicle.
- Reception on the ground of telemetered data fom the vehicle.

Many advantages accrue from the integration of these functions into one system, one of these being the more efficient use of the frequency spectrum —a very important factor, especially for future use. Other gains realized are: reductions in hardware; minimization of weight, size, and power; increased reliability; and simplified logistics.

Guidance Problems

The MAN system will guide a glider-type vehicle, returning to earth from an orbiting path, by first firing it into a ballistic trajectory which intersects the earth's atmosphere at a calculated point. After completion of the re-entry phase, with its extremes of temperature and deceleration, the vehicle must be guided into the correct landing configuration. The landing itself is accomplished by flaring the flight path just prior to touchdown so that there is a safe margin above stall with very little excess speed.

Re-entry of the vehicle takes place within a definite range of altitude-velocity combinations . . . defined as the re-entry corridor. The conditions to be avoided are combinations of high velocity and low altitude — which would cause excessive aerodynamic heating and extreme g forces, and low velocity at high altitude — where the vehicle will be aerodynamically unstable. The guide mechanism must fire, or give the astronaut information for firing, the retro-rockets at the appropriate point with the correct magnitude and direction to bring the vehicle out of orbit and into a preselected path within the re-entry corridor. This can be done, in general by measuring the vehicle's orbit and then calculating the required commands to be sent to the vehicle control system.

Re-entry accomplished, the vehicle must arrive at the general landing area with nearly all of its excess energy dissipated. During the landing approach the vehicle's energy may be dissipated by controlled maneuvers or control of various drag devices as a function of velocity versus range and altitude. A variable drag device is by far the simplest to use since it does not require a computer to calculate the energy removed by a particluar maneuver. As

Continued on page 129

Mr. S. D. Zener, General Manager, Louisville Concrete Service, Inc., Louisville, Kentucky, reports . . . "our service includes seven Crane Carrier Corporation Mixer Master trucks. Six of these are equipped with Century LP-Gas Carburetion Systems. Upon careful comparison with identical gasoline operated trucks, we have recorded an average of 50% *LESS* motor maintenance and tune-up. Savings have also been recorded due to less frequent oil changes. In addition, we no longer suffer loss due to pilferage. The LP-Gas sealed tank system prevents syphoning or other means of looting which occur on gasoline trucks when parked. In addition our drivers report . . .

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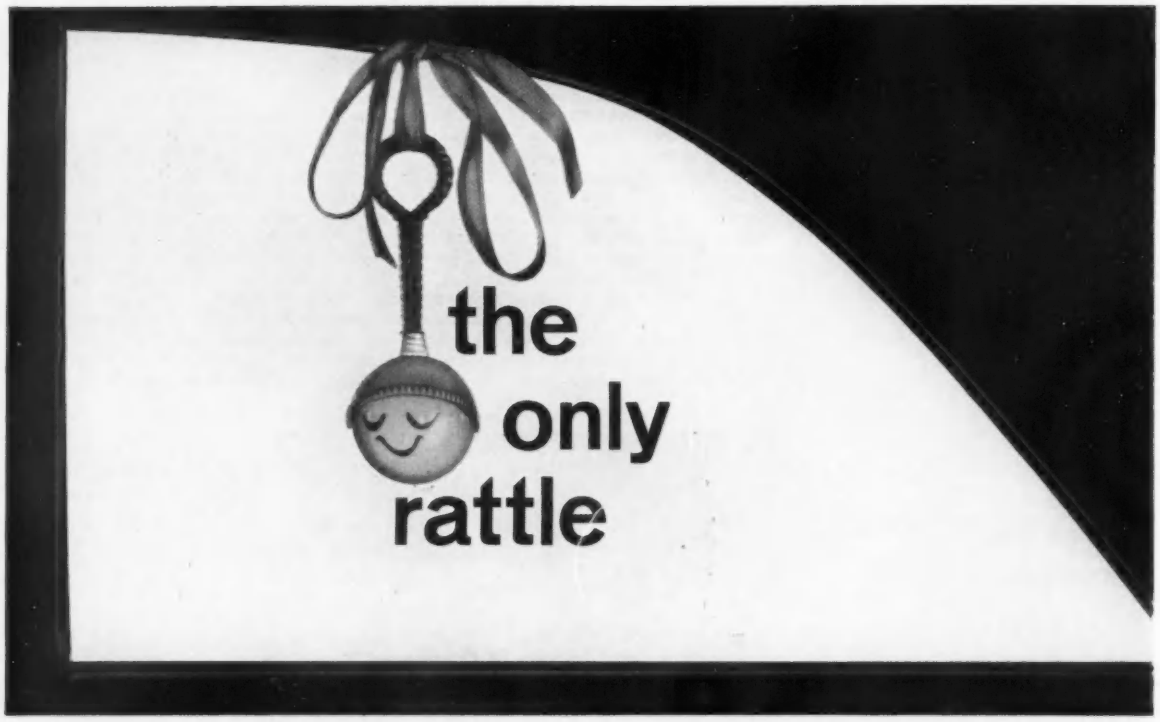

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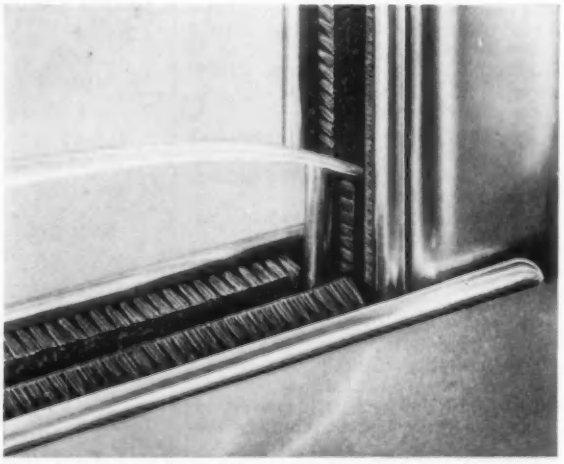

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Continued from page 127

the landing area is approached, the velocity and position requirements are tightened so that the vehicle is funneled into the landing configuration.

In order to land, the guidance system calculates the flare point from accurate data about the vehicle altitude, velocity, and range to touchdown — altitude being the most critical factor.

Equipment Description

The equipment used for the MAN system for landing a space vehicle from orbit may be identified as being either ground-based or vehicle-borne equipment.

• Ground-based equipment — The equipment at the landing area includes an automatic tracking antenna, computers, X-band radar interrogator, data processor, recorders, and communications. This equipment would preferably be mounted in an air transportable van to provide flexibility in selection of flight paths and landing areas. The addition of other ground stations and/or air relay stations chained together would further increase the flexibility of the MAN system.

• Vehicle-borne equipment — The data transponder equipment in the vehicle would consist of a beacon transmitter and receiver, identity coder and decoder, command decoder, and data encoder. This entire package would be miniaturized solid-state equipment exploiting latest component techniques.

For tracking, an eight-foot parabolic antenna is used. The nine-tenths degree beam width used gives an angle tracking accuracy of better than one milliradian rms.

The flight path computer is used to generate the x and y positions and altitude of the vehicle. These data are displayed on a plotting board and used to calculate the commands required for energy management, automatic approach, and automatic landing. The flight data that are decoded by the data processor are also used in these calculations.

The The high X-band is the choice of frequency for the radar interrogator for two reasons: beam width and ion plasma considerations. By using a high frequency the size of the antenna is minimized, for a given beam width. Also, at this frequency, there is a decreasing attenuation by the sheath of ionized gases formed in front of the vehicle by the extreme re-entry temperature. The water vapor and oxygen attenuation is also low at high X-band frequency.

The X-band interrogator used by the MAN System contains a PCM (Pulse Code Modulation) 5-kw magnetron transmitter with a low noise receiver containing an r-f preamplifier. The PCM contains an identity code group and reference pulse preceding the digital message. The identity group is used so that only the appropriate receiver will decode the message and the reference pulse is used for radar ranging.

The command data group transmitter to the vehicle contains five pulses, which provides thirty-one on-off commands. The flight data group from the vehicle to ground equipment consists of eight channels of eight bits. These eight bits can be used to transmit one proportional or eight on-off data signals.

■ **To Order Paper No. 302F . . .** from which material for this article was drawn, see p. 6.

Performance Can Be Better When Cylinders Are Smaller

Based on paper by

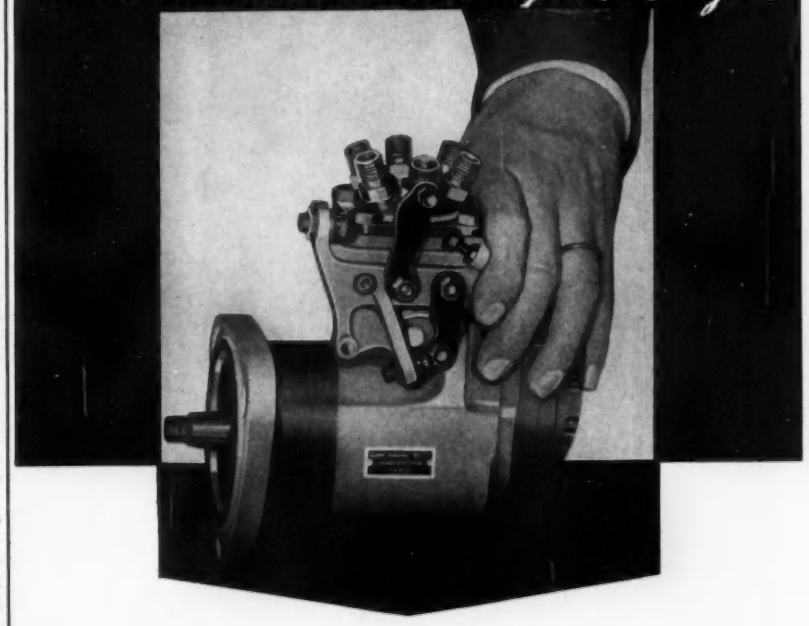
C. FAYETTE TAYLOR
Massachusetts Institute of Technology

FIG. 1 shows that the use of small cylinders in spark-ignition engines can lead to higher specific output, lower specific weight, and better fuel economy, if their potentialities are properly exploited.

Whether or not the advantages of

Continued on page 131

The only injection pump as easy to fit and set on the motor as a distributor on a gasoline engine



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Continued from page 129

small cylinders justify their use in a given application depends, of course, on the particular circumstances. Thus, the performance advantages attainable with the small cylinders must be balanced against considerations of lower cost and fewer parts, inherent in the use of fewer cylinders of larger size to develop the required output.

Fig. 1 is based on a test program being carried out at M.I.T. to study the effects of cylinder size on detonation and octane requirements. Three geometrically similar single-cylinder engines are being used of the following bore and stroke: 2.5 × 3, 4 × 4.8, and 6 × 7.2 in.

Operating conditions of these engines include:

- The same piston speed for all sizes.
- The same fuel/air ratio.
- Best-power spark advance, or spark advance giving peak pressure 20 deg after top dead center.
- The same inlet temperature, jacket temperature, and oil temperature.
- The same exhaust pressure.

In the case of knock-limited imep tests, the same compression ratio is used, and the dependent variable is inlet pressure, which is taken as the pressure that gives incipient detonation, as evidenced on the oscillograph screen.

These tests show clearly that the tendency toward detonation increases rapidly with bore, under otherwise comparable conditions. Two of the factors that appear to be responsible for this phenomenon are:

- Combustion time — At a given piston speed, combustion time tends to be nearly proportional to bore. Thus, the time available for prereactions in the end gas increases with bore, which should lead to increased tendency to dentonate. This is probably the predominant factor.
- Cylinder surface temperature — As the bore gets larger, thickness of piston head, combustion-chamber walls, and valves increases. This trend means increased surface temperatures as the bore increases. It is well known that increasing cylinder-wall temperature leads to increased detonation.

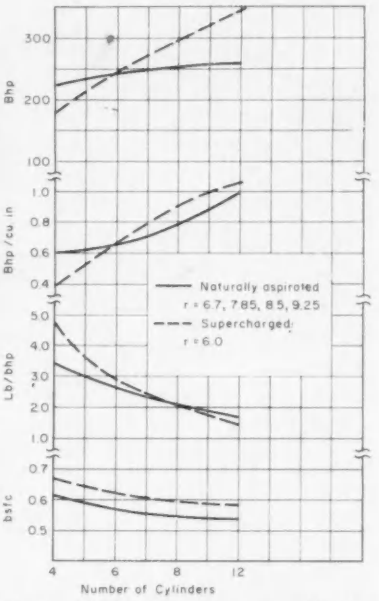

Fig. 1 — Effects of changing number of cylinders and, hence, cylinder size, for a group of geometrically similar engines having same piston area (100 sq in.). Piston speed was 2700 fpm. Knock-limited compression ratio was used for each cylinder size. Engines were run both naturally aspirated and supercharged to their knock limit, with fuel that allowed the 8-cyl engine (taken as a base, and intended to be typical of 1960 passenger-car practice) to develop 175 psi imep, with a compression ratio of 6.

■ **To Order Paper No. 279B . . .** from which material for this article was drawn, see p. 6.

Space Controls Are Made for Long Exposure

Based on paper by

A. B. BILLET
Vickers, Inc.

ONE of the major ways of reducing the effects of space exposure on hydraulic control equipment is the use of integrated packaging. This type of packaging of these space vehicle components offers to solve many exposure problems, a chief one being external leakage. The elevated temperatures found in space, caused by aerodynamic heating and/or solar radiation, are highly conducive to producing leakage conditions, and special effort must be made to combat the situation.

By independently mounting the hydraulic components to the manifold in such a manner as to port all fluid flow internally, external leaking is thwarted. In addition, stainless steel o-rings replace the usual elastomeric seals to minimize leakage in many applications. In other cases, a Viton type A material is used, and sometimes a loaded Teflon seal might be used. Several effective methods of shaft sealing under space conditions have been devised. These include: using a carbon rubbing surface in conjunction with a Viton A static O-ring-type seal, or an all-metal convolute-type seal, or using a welded metal bellows with a carbon face seal. Successful sealing at temperatures up

Continued on page 133

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Sealed Power is also noted for breakthrough engineering achievements which serve the entire industry. One such advance is our Stainless Steel oil ring—now widely accepted by the automotive segment of the reciprocating engine industry. This, and all Sealed Power contributions, are dedicated to our common cause—improving and refining the efficiency of the reciprocating engine.

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Continued from page 131

to 500 F has already been achieved.

Hydraulic fluids to operate in the expected temperature range of 400–700 F have also been found. Disiloxane base fluids have been used quite successfully, for several hundred hours, in operations at the lower end of the temperature range. As the temperatures approach 700 F, the super-refined MLO-7243 petroleum-base fluids have proved satisfactory. For still higher temperatures — in the 1000 F range — such fluids as silicone types, and liquid metals are being investigated. The materials used in the control and pump components of the hydraulic system, to accommodate these high temperatures, are titanium and stainless steel, replacing the more conventional magnesium and aluminum.

The integrated and completely sealed hydraulic system package is also effective in reducing the problems caused by low ambient pressure, such as explosive decompression, vaporization of materials, and absence of dampening vibration.

One other environment factor is felt to be of importance in the design of the space vehicle hydraulic system, and that is radiation. Although much more work remains to be done in the field of cosmic and nuclear radiation research, the effect of this phenomenon on the hydraulic system is not expected to present insurmountable problems. Radiation has a minor effect on elastomers such as natural rubber, but the use of metal O-rings and simplified plug-in-type subsystems can nullify the long-term effects of radiation.

■ **To Order Paper No. 302E . . .** from which material for this article was drawn, see p. 6.

NEW IDEAS Come from People; Not Companies

Based on paper by
LYNN A. WILLIAMS
Anocut Engineering Co.

MOST NEW IDEAS come from individuals. Large corporations are developers rather than creators. Nevertheless, important inventions have been made by men working within the framework of big American business. The idea for the transistor was suggested by Dr. Shockley at Bell Laboratories; freon refrigerants came from Tom Midgley after he had joined General Motors. Coolidge and Langmuir at General Electric and many others in big industrial corporations made many creative contributions.

But, for the most part, the large corporations have been engaged in the

Continued on page 134

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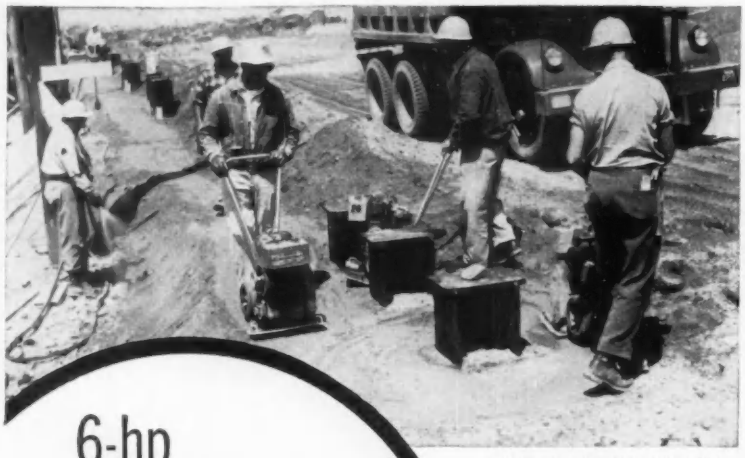

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Continued from page 133

development and advancement of ideas rather than in generation of the ideas themselves.

What has happened in both older and more recent history gives reason for skepticism about any sudden excrescence of invention from our corporate giants. So does examination of the purpose of a large industrial corporation. That purpose is essentially to produce . . . a valid and sufficient purpose, even though industry-criticising sociologists sometimes overlook that fact.

Invention defies planning. Only a small fraction of the men who will contribute ideas to the future can ever be corralled into industrial research laboratories.

If big business wants new ideas, it can help itself some by improving the climate for their growth within business. But it can help itself much more by opening its doors to creative individuals outside the walls. A factory may not be the place to **create** new processes, but it ought to be a place which **wants** new processes.

If we are to have a flow of creativity, of new processes, new products, or new institutions, we must want them. If we want them, we will get them. In the words of Plato: "What is honored in a country will be cultivated there."

■ **To Order Paper No. 277B . . .**
from which material for this article was drawn, see p. 6.

Air Force Proposes Cargo Handling System

Based on paper by

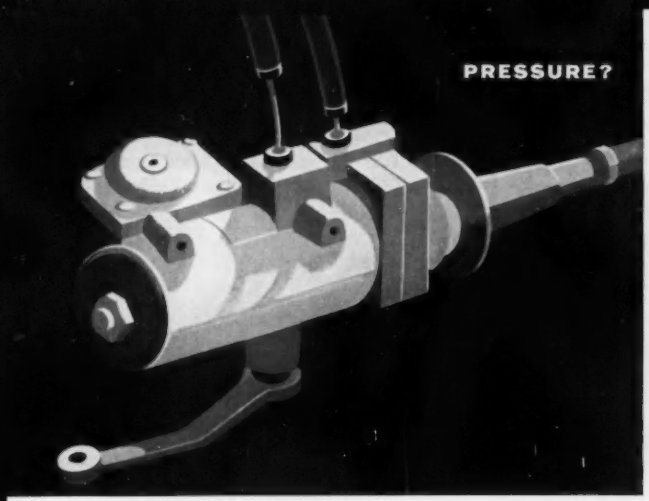
LT. COL. M. E. PETERSON and MAJOR C. M. EDMONDS
USAF, Wright-Patterson Air Force Base

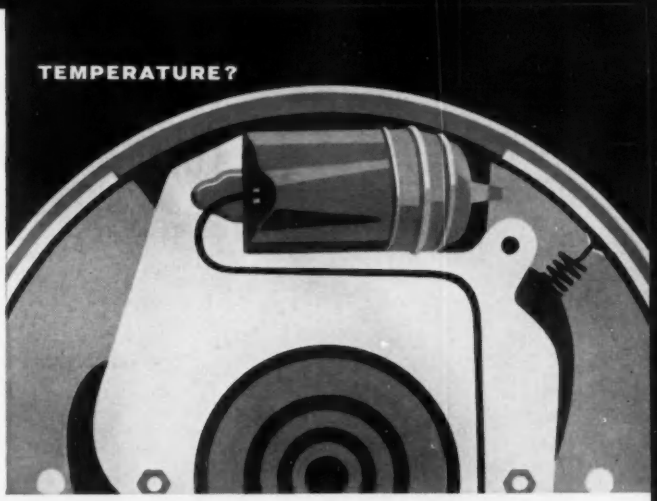
THE materials handling support system (designated System 463L by its Air Force proposer) aims to exploit to a maximum the flexibility, speed, and economy of air transportation. It is based on the unit load, source-to-user concept.

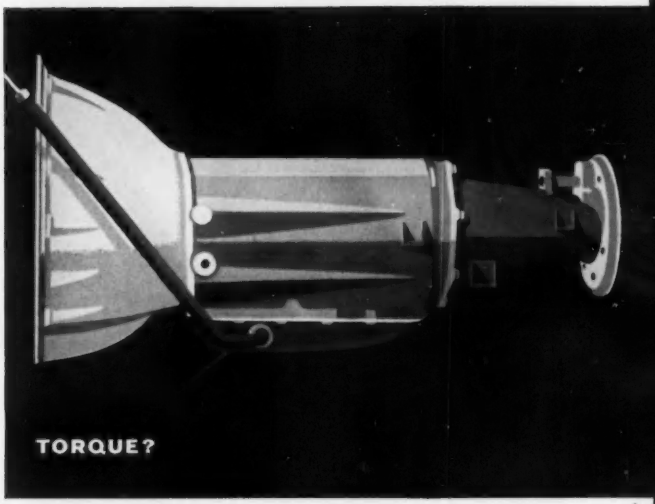
Rigid pallets will be loaded prior to arrival of the cargo aircraft. Where full pallet loads are not available for single destination, modular size disposable containers would be used which would permit easy de-palletization at enroute stations. The cargo load will have to be provided with omnidirectional restraint while in the aircraft.

Pallets are preferred to containers, since the latter are efficient only when the loads flow equally in both directions. Moreover, expendable containers are expensive and the cubage loss is heavy. Permanent containers will

Continued on page 136







POWER PROBLEMS? . . . "tailored" hydraulic fluids meet new physical, chemical demands

New developments and designs in hydraulic systems frequently ask for fluid performances that aren't possible with present materials. And that's where the Dow Automotive Chemicals Laboratory can step in and "tailor" a fluid that will meet just about any physical or chemical need.

For many problems, a ready solution is frequently found by improving the existing formulation—for example, adding a thickener to alter viscosity characteristics. Other problems require a totally new material. Here's where the chemist has a special advantage—if he doesn't *have* the right fluid, he can *make* it! At the Dow Automotive Lab the chemists and automotive engineers are particularly well equipped to create new hydraulic fluids to extremely exacting specifications.

An example: a new Dow formulation was recently developed for a single central-power fluid to actuate steering, brakes, windows, and other accessories. To aid the Automotive Industry, the laboratory resources and experience are available to assist in particular problems.

With Dow's broad background in hydraulic fluid technology and a long list of glycols, Dowanol® glycol ethers, and other polyols, a ready answer to many hydraulic fluid needs may be achieved.

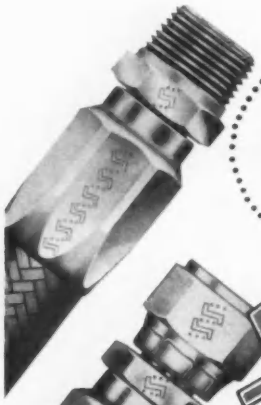
ENGINE COOLING. Ebullient cooling for passenger cars is under continuing research at the Dow Automotive Chemicals Laboratory. The increased flexibility of the system is expected to allow more freedom in the placement of radiators, for example, remote from their present location. This thought is intriguing to designers!

VORACEL® foamed-in-place, rigid urethane is showing real economic advantages over cut-and-paste batt applications. Application of the new water and chemical resistant foam may be either by a spray or pour operation for insulation, structural support, sound deadening, "pocket" sealing, and surface protection.

DOW AUTOMOTIVE CHEMICALS LABORATORY

Created expressly to serve the needs of the automotive industry, Dow's Automotive Chemicals Laboratory is active in technical service and development. This laboratory is continually researching and developing coolants, hydraulic fluids, cutting and grinding fluids, functional fluids, fuel and lubricant additives, and synthetic lubricants. To see how this laboratory can be of assistance to you, contact your nearest Dow sales office or write to Chemicals Merchandising in Midland.

THE DOW CHEMICAL COMPANY DOW Midland, Michigan



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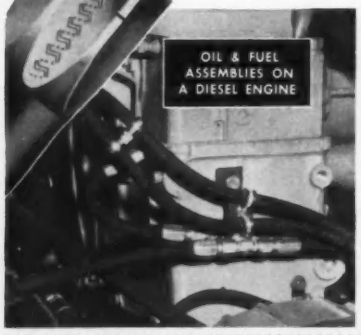
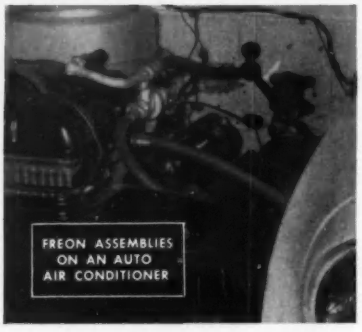
STRATOFLEX HOSE & FITTINGS





VIBRATION PROOF • LEAK PROOF • ABRASION RESISTANT

Manufacturers and users of equipment requiring hose assemblies can depend on Stratoflex flexible hose and hose fittings to reduce downtime through availability, thereby holding maintenance costs to a minimum. Designed for diesel, automotive, general industrial and commercial applications, Stratoflex hose and fittings have the proven durability that is necessary for dependable service. Stratoflex hose and fittings are available in a wide variety of sizes and types to meet every requirement. Shown above are typical installations where Stratoflex hose and fittings are giving economical, dependable service.

For complete information, write for 5-2 bulletin. SF1-1

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Continued from page 134

be used for movement of frozen foods and perhaps expendable containers for fresh foods.

The materials handling must be mechanized to the maximum practical extent. And basic to this is the concept of moving cargo to the aircraft as opposed to bringing the aircraft to the terminals. Obviously, this will require development of new equipment for transporting loaded pallets from terminal areas to parking ramps.

System 463L does not call for a complete redesign of terminals, however, nor is it dependent upon major modifications to existing terminals. A maximum amount of mechanization of freight handling is desirable except in areas where labor is very cheap, particularly overseas. Certain requirements are specified for future terminals and for existing structures which are to be modernized.

The system must be compatible with all forms of transportation — trailer trucks, ocean vessels, and rail flat cars — to make the source-to-user concept effective. It must also be compatible with all types of cargo aircraft, not only as to pallets but to the restraint rail and to the mobile equipment used for loading and unloading the aircraft. Finally, the restraint rail must be capable of supporting air drop missions.

The cargo will be controlled from origin to final destination by a single machine-readable document (punch card). It will be designed to perform the functions of instructing transportation, preparing labels, manifesting, accounting, and reporting. This system will cut paper work and will minimize loss and misdirection of the cargo.

■ **To Order Paper No. 283B . . .** from which material for this article was drawn, see p. 6.

Geology Has Role In Lunar Exploration

Based on paper by

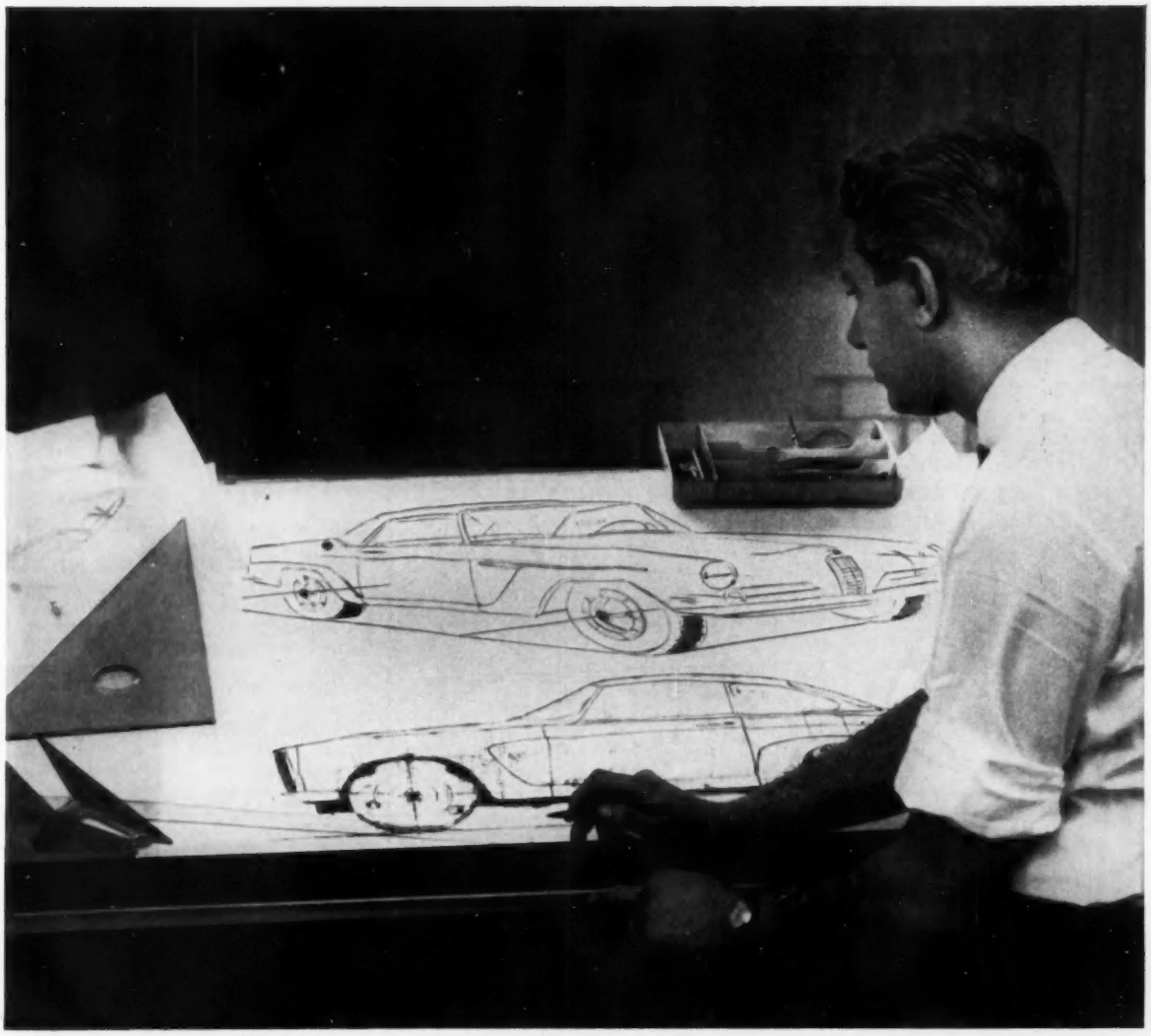
J. GREEN
North American Aviation

THERE'S more to be gained from exploration of the moon than keeping a man alive on that planet. We might acquire understanding of the early history of the earth's crust, the composition of pre-life seawater, and the origin of continents and ocean basins. It might tell us if meteoritic impact or defluidization is a generally operative process.

The application of geology to man's survival on the moon falls into five

Continued on page 138

WHAT'S NEWS IN RUBBER



In design after design...the big switch is to BUTYL!

Automotive engineers have discovered that Enjay Butyl rubber is one of the best ways to improve car performance. Now all U.S. cars contain parts made from Enjay Butyl . . . parts such as weatherstripping, body mounts, engine mounts, radiator hose, accelerator pedals, and many more. Engineers specify Enjay Butyl rubber because...

- *Butyl resists weathering*
- *Butyl deadens noise and vibration*
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- *Butyl beats the heat*
- *Butyl resists tear, flex and abrasion*

Enjay is always ready to help manufacturers build the extra performance of Butyl into their cars. For more information, contact Enjay's Detroit Area Office, 17360 West Eight Mile Road, Southfield, Mich. Phone KEnwood 2-7113.

EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

ENJAY CHEMICAL COMPANY

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Continued from page 136

categories: terrain, rocks, minerals, power, and tools, as follows:

- A knowledge and interpretation of terrain features of volcanic or impacted areas will enable their utilization for protection and concealment. Volcanic landforms offer more terrain advantages than do impacted landforms.
- Optimum use of surface rocks for insulation material, building stone, and water content will be implemented by geological mapping and evaluation. Meteoritic rocks offer fewer advantages than volcanic rocks in providing for these needs.
- The minerology of a volcanic terrain may provide critical elements such as sulfur for use in technology or ice for survival. Meteorites offer iron and nickel as easily obtained by-products.
- The use of heat and power, in whatever the degree available, may be more expediently provided by geological prospecting. Thermal sources on the moon may be radioactive surface rocks, potentially active hot spring and fumarolic zones, and the ray systems and their intersections. Chondrites offer relatively few prospects for radioactive heat sources.
- The geo-scientist may be able to prescribe the optimum tools specific for the exploration needs of the first men on the moon. For example, the neutron-neutron logger is specific for the detection of water and the neutron-gamma deuterium-tritium accelerator logger for chlorine or sulfur. The geophone would be valuable in determining whether surface or subsurface noise were the dominant expression of energy release on the moon.

This article is based on part of an Astronautic Symposium developed jointly by SAE and the Air Force Office of Scientific Research. The Symposium is available only as a book, titled "Vistas in Astronautics — 1960." To order, turn to p. 6.

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43 YEARS OF ENGINEERING LEADERSHIP

What TWO Chevrolet Engineers Think about Modern Transmissions

From introduction to a paper by

F. J. WINCHELL and
W. D. ROUTE

Chevrolet Motor Division,
General Motors Corp.

THE MODERN automatic transmission has accomplished little of optimum performance and economy, but has significantly alleviated the noises and jerks which annoy the customer.

Characteristics of the current internal combustion engine result in probably the most serious compromise in the modern passenger car — its transmission. Over the years the customer has come to accept this compromise (transmission) as an integral part of his car. He is annoyed at having to operate it. But he has little knowledge of the potential gains in performance and economy which the optimum proportions of speed and torque from the available engine power would give him.

A large group of the things about a transmission that annoy a customer are directly related to the transmission output torque disturbances during the ratio change.

The most restrictive aspect of producing commercial shifts is the margin of safety required for the variability and limit stack of all the factors contributing to these particular disturbances.

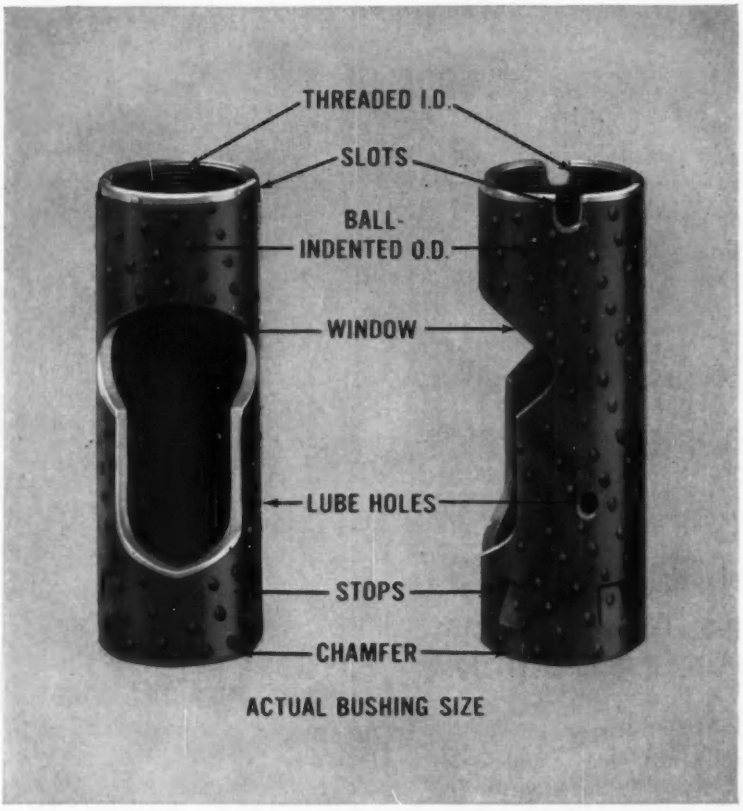
Above all, the shift must not be detrimental to the life of the transmission. But good shifts and extended durability are generally of opposite sense. For instance:

- The softest, smoothest shift is the least apt to live.
- The shift that comes in positively and with great authority is the most durable.
- The combination of softness and durability is usually expensive and space-consuming.

Further, the entire system is degenerative. . . . A reduction in friction coefficient results in higher energy absorption — which results in lower

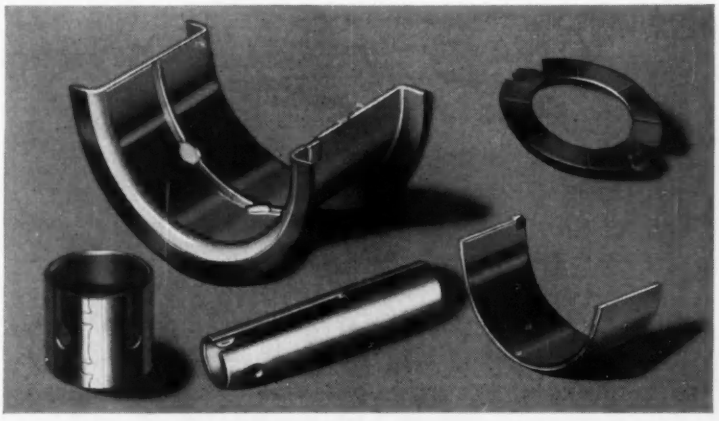
Continued on page 140

"EXOTIC" BUSHING MAKES NEW STEERING DESIGN COME TRUE



INSIDE-OUT BUSHING HELPS PUT NEW STEERING MECHANISM INTO PRODUCTION! To perfect a new steering mechanism, an automotive manufacturer required a linkage component. Designers tried making it of machined steel, then plastic . . . both materials failed. But the unusual bushing shown at left, with a number of features F-M engineers helped designers incorporate, solved the problem. It is bronze-on-steel, formed with the ball-indented bronze on the O.D. so the bushing can accommodate sliding motion within the mechanism. A large window makes insertion of a ball socket easy during assembly. Design of the bushing also includes: stops near one end to hold a disc . . . a threaded I.D. on the other with slots for a locking pin . . . holes that supply lubricant to the outer surface. For the F-M customer, all these built-in features helped accomplish this result—easy, efficient assembly and success with a new design.

CAN F-M BUSHINGS SOLVE problems on your board or on your assembly line? Or perhaps a sleeve bearing, thrust washer or spacer? F-M, who makes them all, can provide the answer. F-M engineers, with a wealth of knowledge from years of experience, are available to help design the needed component. This complete technical assistance is one reason why these F-M products are widely specified for use in automobiles, farm equipment, construction machinery and many other products.



Additional information about bushings is provided in a Design Guide, published by F-M. Helpful literature is also available on sleeve bearings, thrust washers and spacer tubes. For your copies, write Federal-Mogul Division, Federal-Mogul-Bower Bearings, Inc., 11035 Shoemaker, Detroit 13, Michigan.

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Continued from page 138

friction coefficient. . . . All the factors making up the durability of the system are in series, with failure of the friction elements and immobility the end product.

Maladjustment of linkage, for example, can result in loss of pressure. Loss of pressure results in loss of applied force — which reduces the clutch torque, increases the energy, reduces the coefficient of friction, etc. The debris, consequent to incipient failure, clogs the screens or sticks the valves. This results in further loss of pressure. . . . Almost every malassembly or malfunction, in fact, results in failure of the friction elements.

Degeneration of the friction elements may start with an oil leak, improper filling, overheating, deterioration or oxidation of the oil, a worn pump, improper band adjustment, debris from original assembly, an incipient bearing failure, or maloperation.

Even the operator's knowledge of the transmission can be a degenerative factor. The initial phase of the process is so subtle that he doesn't recognize it. He may even like it. . . . As the end approaches, when it exhibits some reluctance to go in the preferred direction, his reaction is to increase the throttle with ever-increasing damage. The vehicle immobile, and the engine racing at its terminal speed finishes the cycle and the friction elements.

Transmission Engineer's Job

The transmission engineer's job, then, is not to set up a Proving Ground demonstration of his ability to make one very smooth calibration of one transmission. . . . This phase of the evolution is reserved for the inventor.

Neither is it to produce one abrupt, but durable shifting transmission . . . this is the forte of the development engineer.

The job of producing millions of inoperative transmissions belongs to the process engineer.

The transmission engineer's job is to make enough transmissions work well enough, enough of the time, under enough circumstances to make satisfied customers as well as a profit. If his margin of safety is too great or too small, his competitors will beat him!

To Order Paper No. 311A . . .

. . . in which these authors present a detailed, mathematical discussion of the fundamental relationships involved in "Ratio-Changing the Passenger Car Transmission" — designed to permit the transmission engineer to best exercise his ingenuity — **see p. 6.**

. . . C.R.O. UNIT STEPS UP TRACTOR "SHOE" PRODUCTION!

This spark generator (illustrated) is used on an automatic flame cutter developed by C.R.O. Engineering Co. Inc., of Milwaukee.

The unit eliminates 3 punch press operations and effects a drastic cut in floor space (from 250 to about 10 feet) in the manufacture of crawler tractor shoes.

Mr. R. W. Kleine of C.R.O. comments on selection of the Wico XH magneto as original equipment:

"We needed a magneto which could be readily adapted to our special mounting and motor drive. We also needed a magneto which would have a surplus of spark generating power . . . After putting these units in operation we have found that they have met our requirements in every respect. We have been able to adapt this igniting unit to automatic flame cutting machines, and the reliability and perfect performance of the unit results in "lights" every time. The spark generating capacity of the unit is such that even though the electrode is out of adjustment by an unreasonable amount, the ignition still takes place instantaneously."

If you have an ignition problem, see your nearest Wico distributor — or write:

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Higher Energy Yields Sought from Batteries

Based on paper by

J. J. LANDER

Delco-Remy Division, General Motors Corp.

MARKED advances in electrochemical energy utilization on a weight basis are to be obtained by exploitation of materials which can be used with fused-salt electrolytes or in fuel cells.

Certain characteristics are inherent with the use of fused-salt electrolytes. They are:

- High unit cell voltages become possible because the very active and light-weight alkali and alkaline earth metals can be used. They are compatible with their fused-salt electrolytes.
- Excellent electrode kinetics are to be expected because the simplest kinds of electrode reactions can be utilized — the solution and deposition of ions from their salts or salt mixtures.
- Electrolyte conductivities in molten salts are the highest known and are a full order of magnitude better than the best water-base electrolytes.

These batteries have major drawbacks. They have to be heated to be activated, and in applications where the heat source has to be engineered

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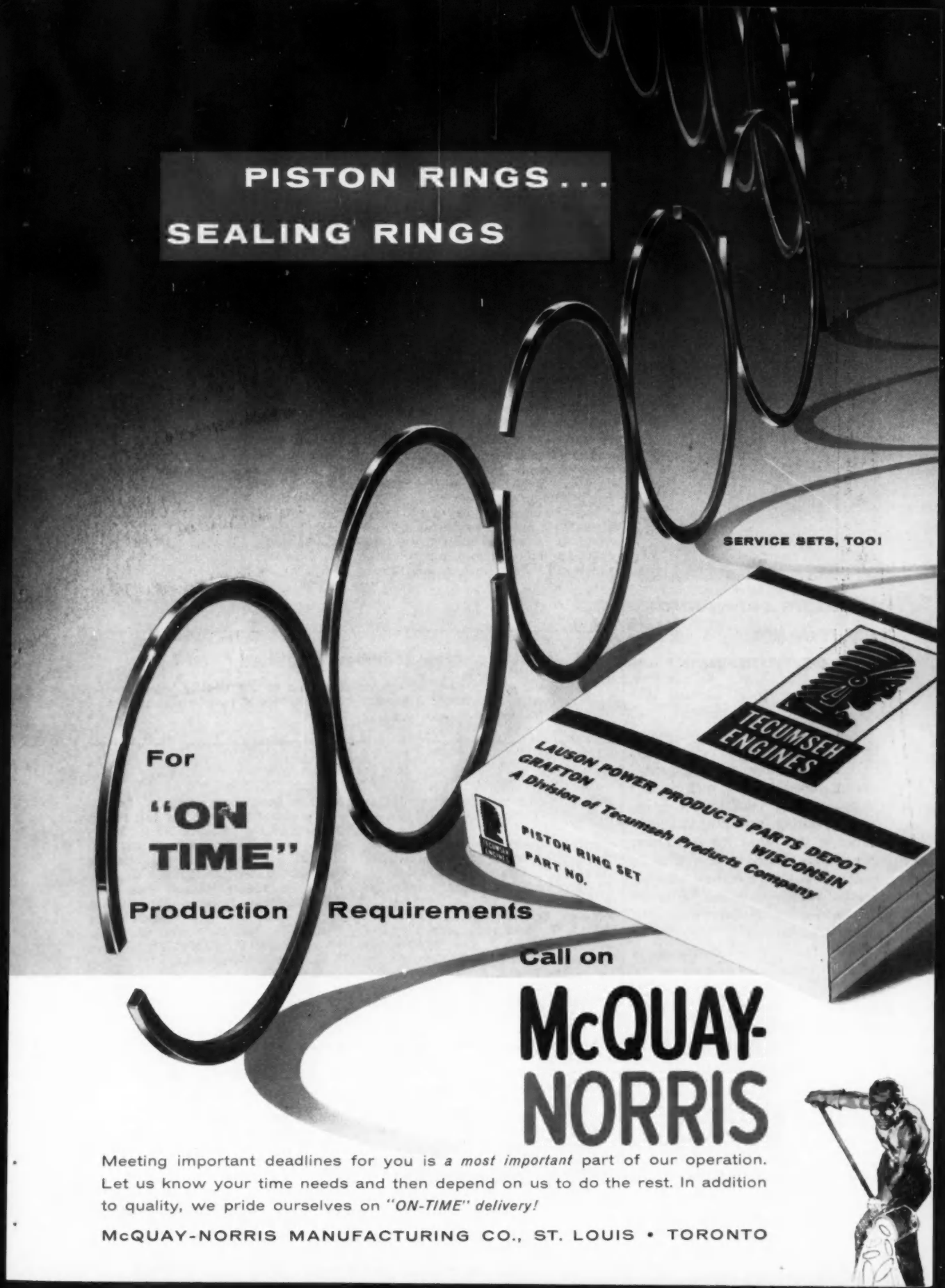

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Continued from page 140

into the battery as an integral part, energy yields on a weight basis will be reduced.

Fuel Cell Advances

Of the fuel cell types under development, those which operate on hydrogen and oxygen or hydrogen and air are the best developed. Electrode kinetics are simple and fairly good at low rates and, because water is the reaction product, its elimination is simple in concept. Low-temperature cells operating at atmospheric pressure have been run at low rates up to thousands of hours at overall energy efficiencies up to 80%. Without doubt complete systems can be designed which could approach 200 w-hr/lb on the basis of today's state of the art. Power per unit weight of cell values of 10–20 w/lb can be achieved.

High-temperature (200 C), high-pressure (40 atmospheres) cells are under investigation. These exhibit better electrode kinetics, as would be expected. Power values of 50 w/lb of cell weight might be achieved.

Regardless of temperature or type of fuel cell, present power ratings suffer from a combination of electrochemical and engineering problems which will have to be overcome. There are problems of electrode construction to obtain highest gas-electrode-electrolyte interface; of selection, preparation and application of catalytic materials to the electrode material, and of the efficient removal of water at high rates of discharge. Also, high-temperature, high-pressure operation will call for auxiliary equipment for the more complex control.

Within two to four years, solutions to these problems should result in doubling the power per unit weight yields of electrodes and extend electrode life at the same time.

Comparison With Diesels

If fuel economics is disregarded and a comparison is restricted to power output per unit weight, the hydrogen-oxygen fuel cell can be said to approach a competitive position with the diesel engine because it requires a performance increase by a factor of only two to three times if the power rating of a diesel is accepted as being about 75 w/lb. The fuel cell still has a long way to go to become competitive with the gasoline engine in power output at about 250 w/lb.

(Material in this article is drawn from one of 12 papers included in SAE Technical Progress Series, Volume 3: Storage Battery Symposium — 1961. To order this publication, TPS-3, see p. 6.)

New Members Qualified

These applicants qualified for admission to the Society between February 22, 1961 and March 22, 1961. Grades of membership are: (M) Member; (A) Associate; (J) Junior.

British Columbia Section: William Alexander Taylor (A).

Central Illinois Section: Raymond Edwin Diefendorf (A), Don R. McGuire (J), Edwin L. Riedesel (J), Ray Shipman (M), Frank G. Siler (M).

Chicago Section: R. J. Aberle (A), George T. Fiala (M), John D. Olson, Jr. (A), William J. Ries (M), William Norman Schink (M), William Gordon Stilke (J), Carson J. Ward (J).

Cleveland Section: Francis H. Pascoe (M), William Rodgers (M).

Dayton Section: William E. Metzger (A).

Detroit Section: Robert Harvey Alford (M), D. Robert Bell (M), James Edwin Benjamin (J), Paul R. Blecki (A), Roger Edward Brown (A), C. Borden Chase (M), Theodore F. Cohassey (A), Arie Groeneveld (J), Eugene Bernon Hilker (M), William David Horn (M), Maurice Leising (J), John W. Lovett, Jr. (M), C. Carl Marcucci (J), Frank T. Melcher (M), Robert Walter Militzer (M), Dave Sharad Mohanlal (J), Harold A. Moore, Jr. (A), George Richard Muster (J), Ronald J. Narlock (J), Robert Hanson Plew (A), Edward Hyram Roberts (M), Thomas H. Rutledge, Jr. (A), Thomas Allen Skemp (J), Jack J. Somma (J), Mark J. Sturtevant (M), Paul C. Timmerman (M), John S. Wreford (A).

Fort Wayne Section: Jerry D. Bolds (J), Donald Gene Murphy (A).

Hawaii Section: Jack M. Brown (M), Edward T. Wilson (A).

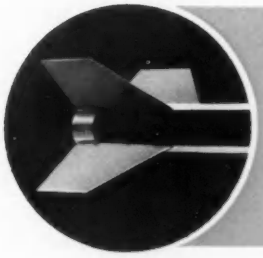
Indiana Section: Richard M. Coulter (A).

Metropolitan Section: Andre Thomas Abromaitis (M), Robert Joseph Fabian (M), Kenneth H. Kirgin (M), Harold McDonald (M), Ivan Pour (M), Theo-

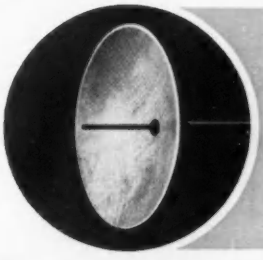
Continued on page 144

CAN BONDING DO IT BETTER FOR YOU?

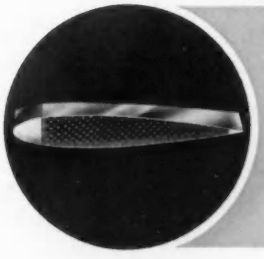
IN A RAPIDLY INCREASING NUMBER OF MANUFACTURING OPERATIONS, THE ANSWER IS YES... bonding can do a better job and can do it at less cost! Rohr is a pioneer in adhesive bonded metal techniques and structures and is projecting this unparalleled capability to the solution of many new manufacturing problems.



MISSILE AIRFRAMES AND BODY SECTIONS, such as this Rohr-built missile fin, can be made better and faster with bonded structures. Ideal strength/weight ratios, cleaner aerodynamic surfaces, better structural integrity for exposure to sonic vibration and long stand-by periods, lower tooling and production costs . . . just a few of the superior qualities of bonding.



RADAR REFLECTORS AND ANTENNAS are among the precision products made better by bonding. No other method provides such dimensional stability and accuracy, plus light weight and fine surface finish.



HELICOPTER BLADES, too, can be made from new bonding methods and materials developed by Rohr. The blade section illustrated is made with non-perforated honeycomb core . . . a technique which is also ideal for aircraft control surfaces.

These examples are but a few of the many ways that metal bonding is doing a better job. For more information about this, or other Rohr capabilities, write Mr. A. R. Campbell, Sales Manager, Department 41, Rohr Aircraft Corporation, Chula Vista, California

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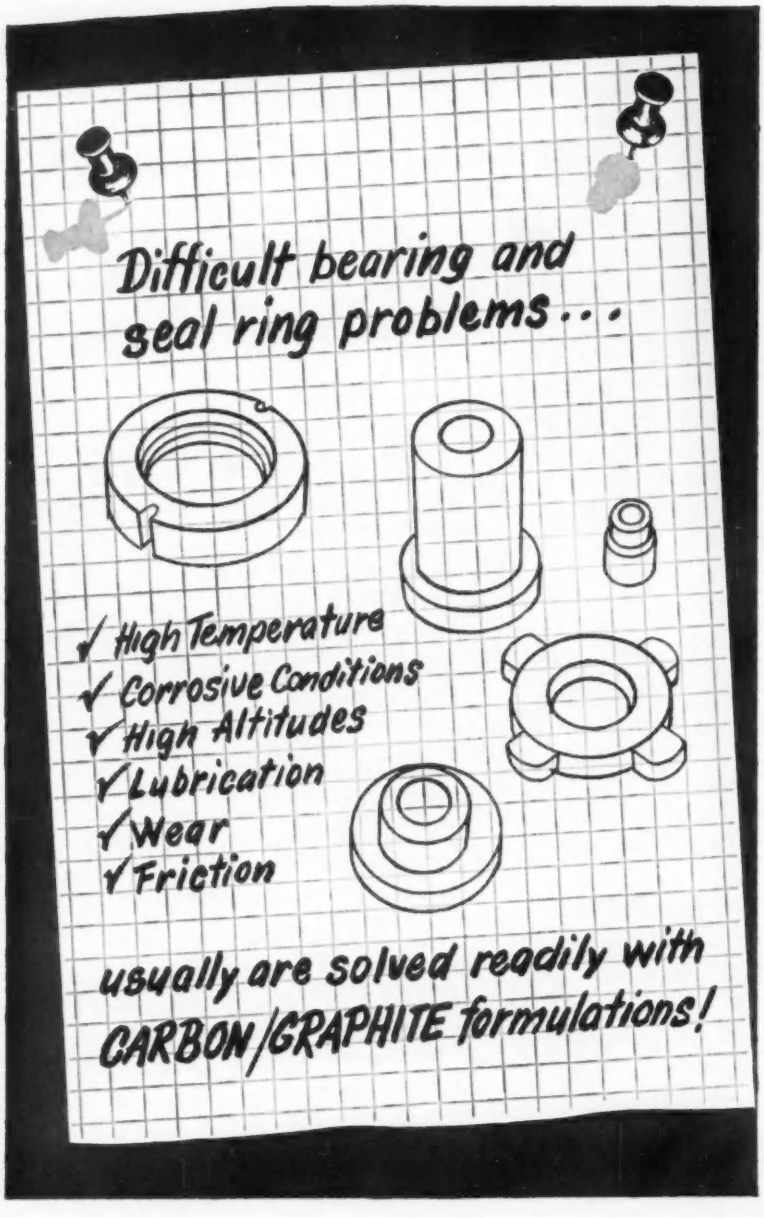

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New Members Qualified

Continued from page 142

dore Christopher Sauer (M), Robert Scott Stahr (M).

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Mid-Michigan Section: Robert L. Houser (J), James E. Marshall (M), William E. Pearson (M), Jerry Myron Roethlisberger (J), Joseph A. Stearns (J), Ralph Dudley Whittier (M).

Milwaukee Section: Robert Harold Jensen (J), Charley Kademian (M), Robert S. Reaves (M).

Mohawk-Hudson Section: John Edward Mulkins (A).

Northern California Section: Earle E. Dodd (A), Owen R. Knop (A), Richard Stanley Shaw (J), Loren N. Williams (J).

Ontario Section: Gerlad J. Ray (M), Hans G. Reichmann (A).

Northwest Section: Vernon I. McCullough (M), Maynard Lyman Pennell (M).

Oregon Section: Roscoe W. Davis, Jr. (J).

Philadelphia Section: Milton Ginsburg (J), Ralph Porsia (A).

Pittsburgh Section: Howard H. Nuernberger (M).

San Diego Section: Arthur H. Pabor (M).

Southern California Section: Ben G. Franco, Jr. (J), Capt. John L. Holloran (A), Newel Whitney Johnson (J), Kirke Leonard (M), Frederick P. Morgan (M), Branson Moore Payne (A).

Southern New England Section: Harry T. Burgess (M), F. Richard Wocasek (J).

Twin City Section: Howard M. Pollari (M).

Williamsport Group: Milton Ronald Lederer (J).

Outside Section Territory: John Joseph Kass (J), Robert Stewart Pringle, III (J).

Foreign: Harjeet Singh Dhindsa (J), India; Nihal Chand Sehgal (J), India; Josephus van Rosevelt (A), Holland; George Verghese (J), India.

Continued on page 149

STROMBERG CARBURETOR MILES-PER-GALLON HELPS KEEP HAPPY OWNERS HAPPY

"You know—there's just one way to keep a satisfied car owner satisfied. And that's to provide him with carefree, trouble-free performance. What he wants is dependable operation, good gas mileage, and easy starting."

"That's right—and one easy way we can do it is by specifying STROMBERG*—the carburetor that's built by Bendix—a pioneer of better fuel systems for over forty years."

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Eclipse Machine Division
Elmira, New York

THE Bendix CORPORATION

working with

Du Pont DELRIN®
acetal resins

one of Du Pont's versatile engineering materials

Ball seats of DELRIN® give "greased-for-life" joints

For many 1961 cars, ball seats in a lubricated-for-life steering linkage are molded of Du Pont DELRIN acetal resin. This new steering system offers smoothness of operation and ease of handling not achieved with other steering linkages. A careful consideration of the functional requirements of ball seats in this application led to the choice of DELRIN.

First, the material chosen needed to have a low coefficient of friction against steel, and the static and dynamic coefficients of friction had to be about the same to give a smooth, even feel to steering. DELRIN has the required frictional properties.

Second, the material had to be tough over a wide range of temperatures (-40° to 250°F.). DELRIN is.

Third, the material had to be unaffected by any solvent action of the lubricant up to 250° F. DELRIN has the chemical resistance needed.

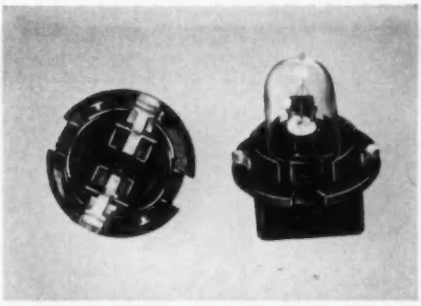
Fourth, the material had to be dimensionally stable under the load and in the environmental conditions encountered. DELRIN is.

Severe laboratory and road tests proved that DELRIN acetal resin had the high strength and resilience necessary to maintain a permanent tight fit.

This is one example of the ways in which the remarkable properties of DELRIN are being used today to improve the performance and to lower the costs of automotive components.

There are more examples on facing page.

Point and breaker spring assembly for automotive fuel pump is made of a single part of DELRIN, replacing a screw and two machined phenolic-laminate parts. Assembly is a simple, fast operation which eliminates a tapping operation. DELRIN provides the superior heat resistance, toughness and dimensional stability required. (Molded by Arjay Mfg. Co., Vassar, Michigan, for Electric Autopulse Div., Walbro Corp., Cass City, Michigan.)



Lamp socket molded of DELRIN is designed for use in dash lighting and other assemblies using printed circuits. It accommodates new socketless bulbs. DELRIN acetal resin provides the required high-temperature resistance, creep resistance, electrical properties and resilience . . . and does so at lower cost than other materials. (Lamp sockets are manufactured by Wade Electric Products Co., Sturgis, Michigan.)

One-piece moldings of DELRIN® simplify design and lower assembly-line costs

One important variable in the cost equation is, of course, the cost of assembly and installation. In this area, DELRIN often makes possible design simplifications by the use of one-piece injection moldings instead of multi-part assemblies. The three products shown above illustrate the point.

For additional information on the properties and applications of DELRIN in the automotive field, mail the coupon below. The same coupon will bring you relevant information on any of Du Pont's versatile engineering materials.

Disc retainer guide of DELRIN replaces conventional stem and stem guide of bronze in foot and line check valves. Guide of DELRIN gives improved flow characteristics, reduced pressure drop, longer life . . . is designed for use up to 180°F. in water, oil or gasoline pumping installations. (Molded by Holman Manufacturing Co., for White Flomatic Division of Flomatic Corporation, both of Hoosick Falls, N. Y.)

POLYCHEMICALS DEPARTMENT

DU PONT

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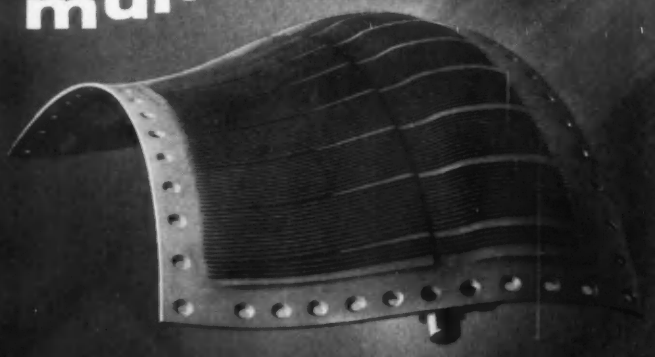
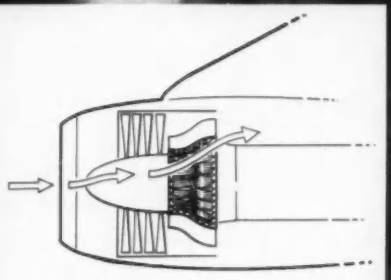
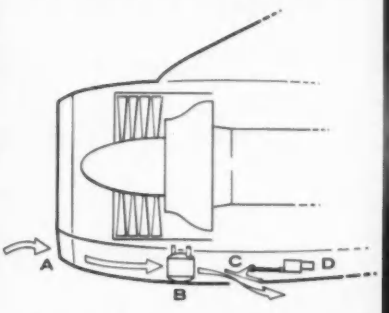
A REVOLUTIONARY CONCEPT IN HEAT TRANSFER DESIGN

multicontoured heat exchangers reduce size, weight and drag...





Multicontoured oil cooler is section of fan exhaust duct



Conventional oil cooling system includes: A. Duct B. Heat exchanger C. Door D. Actuator

This finned surface oil cooler, used for cooling constant speed drive or turbocompressor lubrication oil circuits, is a structural member of the fan exhaust duct. This eliminates the need for air scoops and special ducting.

These installations are already in use on Boeing 707-720B turbofan aircraft and may be shaped to any configuration at extremely close tolerances. Comparable in price to conventional heat exchangers, they are even more reliable and have a longer service life because of their basic simplicity.

Unique manufacturing techniques developed at AiResearch enable this aluminum unit of welded and all-brazed construction to withstand severe structural and pressure loads. Similar units have been developed for non-by-pass gas turbines and ram air ducts. This major breakthrough in heat exchanger design and fabrication is the result of more than 20 years of experience by the company in the design, development and production of heat transfer equipment.

• *Please direct inquiries to the Los Angeles Division*

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AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems and Components for: AIRCRAFT, MISSILE, SPACECRAFT, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

Applications Received

The applications for membership received between February 22, 1961 and March 22, 1961 are listed below.

Alberta Group: Bramwell Herbert Booth, Robert T. Hodson
Atlanta Section: James F. Frenchi

British Columbia Section: Karl Becker, Ernest Davidson, Harvey Cecil Marsh

Buffalo Section: John Albert Adamek, Robert Wilson Bowler, James Richard Cassano, Charles Cook Eckles, Herbert D. Tuttle

Central Illinois Section: George W. Hakes, James Thomas Hammond, Robert Hennelly, Ralph Cooley Herdrich, Dale Kempf, Engene Kobosky, William A. Mitchener, Lloyd Ernest Terry, Charles H. Symonds, Larry G. Warren

Chicago Section: Gene D. Amante, Ralph S. Frost, Carl Hilton, Thomas J. McCook, Robert Jack Melnick, William George Rogal, Richard Jacob Schweitzer, Jr.

Cincinnati Section: William Philip Haney

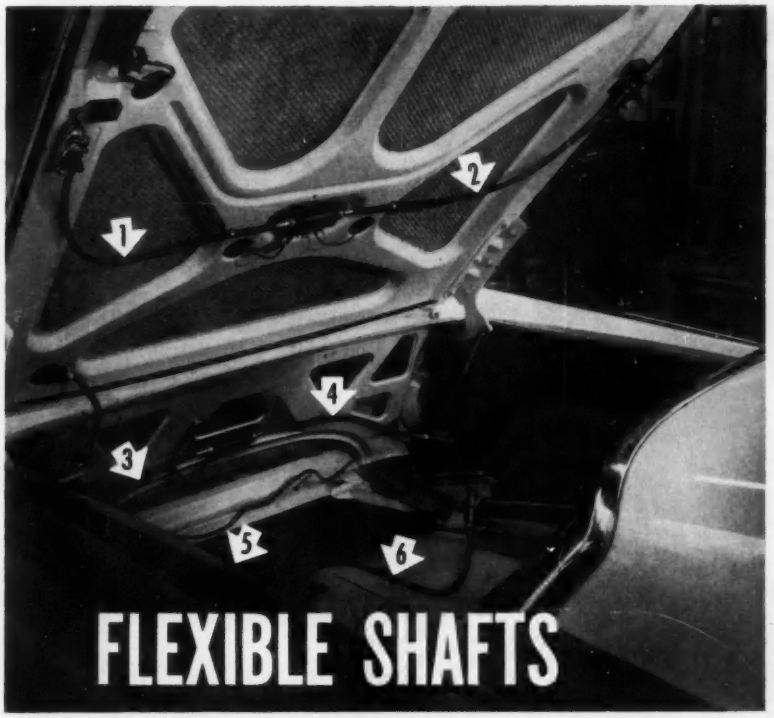
Cleveland Section: Harold A. Frost, James Sidles

Colorado Section: Robert William Miller, William Edward Zebley

Dayton Section: Ronald Walter Bennett, Leroy Carter, Robert Myron Kerns

Detroit Section: Dale Clarence Adams, Michael Anthony Bowen, Raymond Edwin Brooks, James D. Brown, Edmund John Brune, Ronald Norman Burns, Allen Keith Carpenter, William Lee Carpenter, Charles George Crocker, Peter Arthur Danielson, Thomas J. Dedo, Edmand Lewis Elledge, Paul E. Ericson, William John Flower, Harry John Foehringer, Donald Friedman, Gerald Edward Goslin, John Alton Hall, Robert F. Hulett, George Nicholas Ivankovics, Norman Stout Knauss, Steven Albert Major, Berj Missak Manoukian, Marvin Allen Maten, Jr., Januarius Arthur Mullen, Edwin Arter Norris, D. Rene Politis, James M. Ritchie, Jerome Robert Singer, Roy Hamilton Sjoberg, Jr., Richard Leslie Smith, William Sobkow, Donald Casteel Stoeckel, Thomas Harlod Wendt, Gale F. Woodbury

Continued on page 151



FLEXIBLE SHAFTS

simplify retractable roof

In a recent retractable roof mechanism, the roof retracts into the trunk, and the trunk lid closes and locks. All this is done automatically, within 40 seconds. Powering this ingenious mechanism are six $\frac{3}{16}$" high speed, remote control flexible shafts, driven by three reversible electric motors.

The use of flexible shafts enabled the designers to use only one motor to drive each pair of actuators, thus solving synchronization problems and at the same time cutting down on the number of motors needed.

Flexible shafts (1) and (2) rotate the trunk lid locking screws in and out of engagement. Flexible shafts (3) and (4) drive a pair of screw-jack actuators to raise or lower the trunk lid. Flexible shafts (5-not shown) and (6) drive a pair of actuators and their associated linkage to raise or retract the roof.

Investigate for yourself how flexible shafts can solve many of your design problems and reduce costs!

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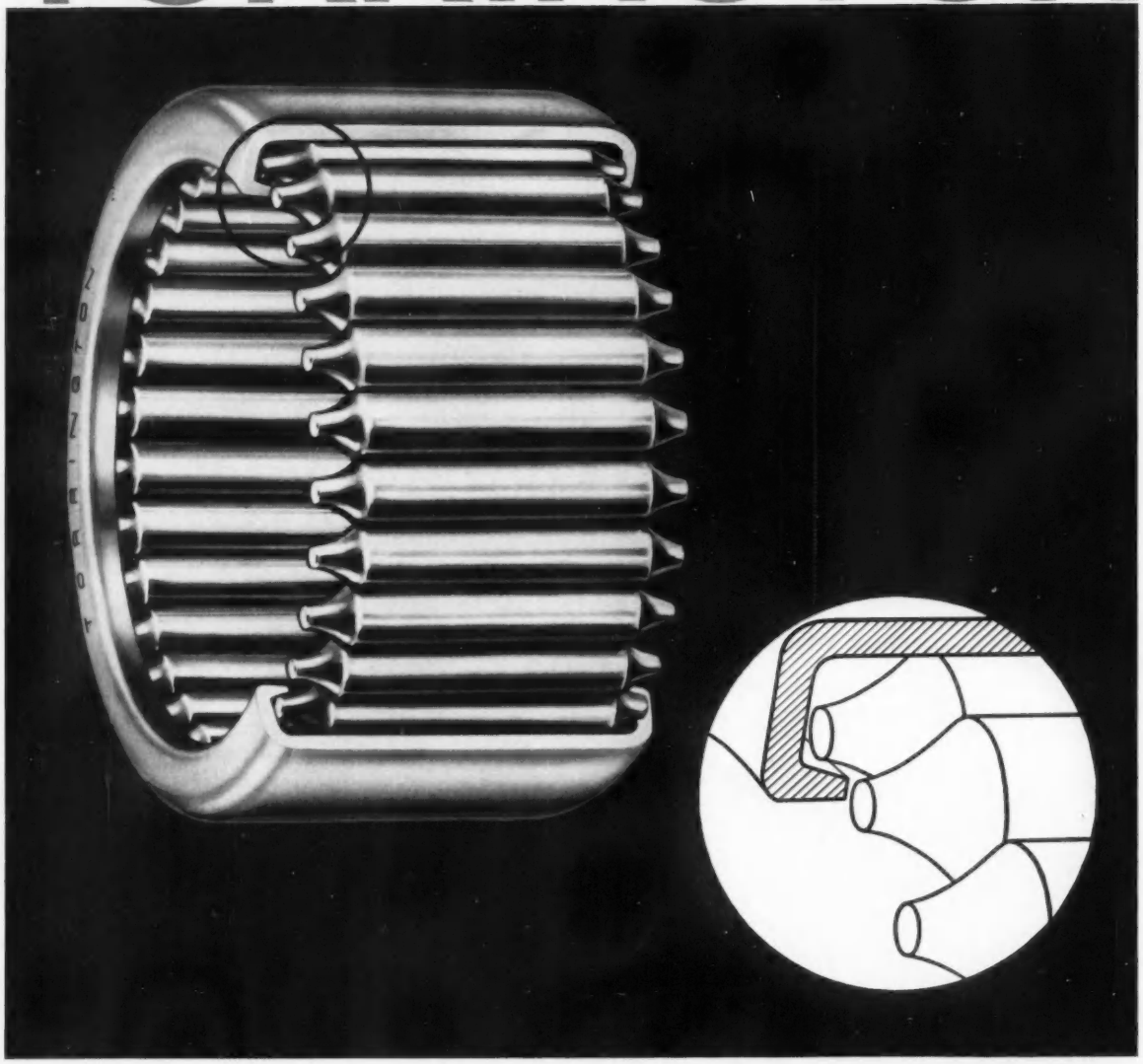

NEVER A SLIP 'TWIXT THIS CUP AND LIP

The Torrington Drawn Cup Needle Bearing is one of the easiest of all bearings to install and maintain. Secret is the turned-in lip construction. This lip positively retains the rollers... keeps them in position as a complete unit during all handling and assembly operations. Install it by simple press fit. No snap rings or shoulders are necessary.

That's not all. The Torrington Drawn Cup Needle Bearing also gives you a higher radial load capacity than any other bearing of comparable size. Precision rollers insure smooth, highly efficient performance, with a minimum of starting and running friction.

This bearing is compact, lightweight, economical. Its unit cost is surprisingly little. For details on how the Torrington Drawn Cup Needle Bearing can help your product, call or write Torrington... pioneer in needle bearings and maker of every basic type of antifriction bearing.

progress through precision

THE TORRINGTON COMPANY

TORRINGTON BEARINGS

Torrington, Connecticut • South Bend 21, Indiana

Applications Received

Continued from page 149

Fort Wayne Section: Robert Lee Dowler, Richard Ervin Lee

Hawaii Section: Robert Stewart Baxter, Alson Lee, Edwin R. Sorensen

Indiana Section: Richard Bailey, Frederick Sylvester Clevenger, James D. Coffelt, Everad A. Comstock, Donald Lee Hollands, Ralph H. Katzenberger, David Ross Thompson, Robert R. Wilson.

Kansas City Section: W. David Barker

Metropolitan Section: Donald B. Allen, Ray John DeChaine, John Anthony Diaks, Henry R. Killian, Jr., Salvatore Negri, Donald John Raphael, Richard Charles Sasse, Curtis M. Stendahl, Ray Livingston Vroome

Mid-Continent Section: David A. Edgecomb

Mid-Michigan Section: Herbert Joseph Stange, John Suppes, Jr.

Milwaukee Section: Charles Joseph Baumann, Donald George Bethke, James John Carravetta, James F. Efflandt, Lawrence LeRoy Flaugher, Richard Edward Lietz, John Patrick Mahoney, Thomas Arthur Mulhaney, Karl Edward Richter, Walter John Zahn

Montreal Section: Christopher T. Newton

New England Section: John E. Calley, James E. Cumming, Frederic G. Davis

Northern California Section: Ronald Eugene Marsolek, Robert Edward Rahtz

Northwest Section: Robert Daniel Hayes, James Henderson Roberts

Ontario Section: Thomas De Boer, Charles Douglas Metcalfe, Derrick Henry Trenholm Millard

Philadelphia Section: Walter G. Arnold

Pittsburgh Section: Harry Walter Jacob, Carl William Straits, Robert Charles Swagler, James William Vance

St. Louis Section: Roger E. Hatton, James John Rezny, Edward C. Sarlls, Jr.

Southern California Section: Zola Fredrick Carper, Sang Ho Choe, Richard Irven Hoyal, William Brendan McStay, Robert French Sarver, Robert L. Scott, Clare E. West, Lewis S. Whitmore, Thomas Francis Warren

Southern New England Section: Paul Edmund DesRosiers, Jack Lester Gorr, Billie Woodroe Wellman Donald R. Muzyka, Wilfred V. Warner, Sr., Alfred Knowles Wood

Southern Texas Group: James Loyd Hill

Syracuse Section: Walter Clayton Dette

Texas Section: Charles Herbert Allen, W. R. Rotenberry

Texas Gulf Coast Section: Harold L. Gann, Walter Wendell Kroupa, Jack Edgar Spell, Joe F. VanMeter

Washington Section: William W. Sullivan

Western Michigan Section: Jerome Kermit Gensler, Mervin Russell Patterson

Outside Section Territory: Carl Joseph Anglin, George C. Landon, Lt. Charles H. Ulrich

Foreign: Raul Oscar Capuano, Argentina; T. B. Ramakrishna Rao, India; Muthusamy Wesley Samuel, India

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Improvements in tappet design, materials, and manufacturing methods are under continual study at Johnson Products for one reason—*better tappets are our only concern.*

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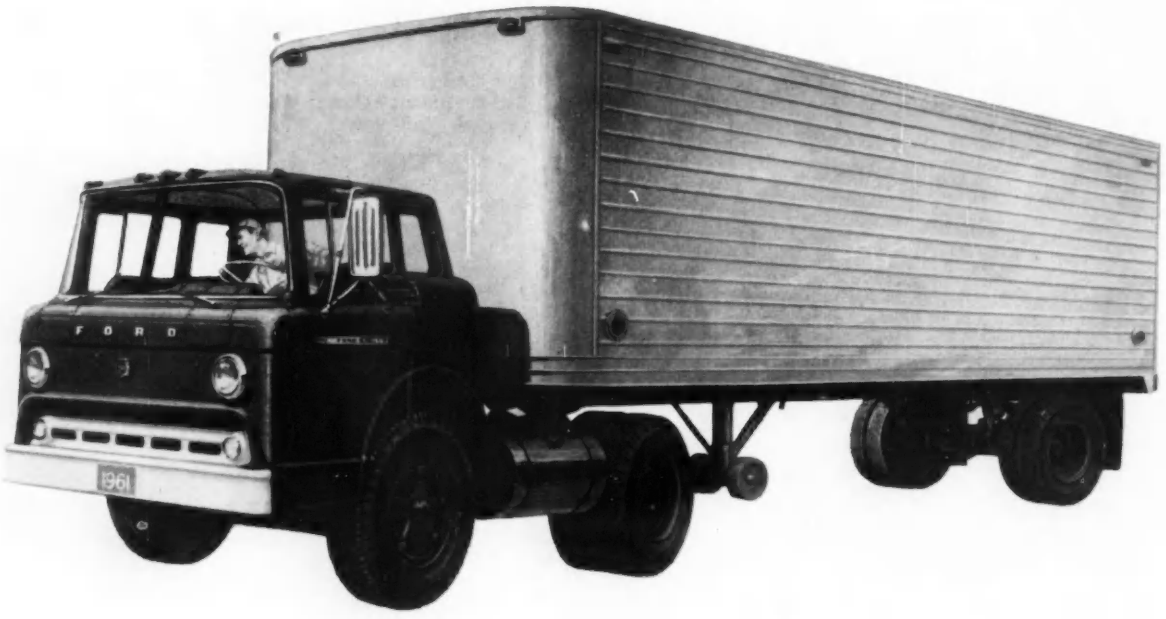

232 FORD TRUCK MODELS

now available with Clark transmissions

Yes, over 230 current Ford truck models contain Clark transmissions as either standard or optional equipment.

Most of this usage is in the tilt-cab and other *bigger* model lines.

A Clark 250V transmission, for example, is optional in the Ford C-550 line. The same transmission is standard and the Clark 265V optional in the F-700, B-700, T-700 and C-700. Same units are available in the F, B, T and C-750 (illustrated) . . . and in the Ford F-800.

Clark transmissions have proved highly reliable in all applications. They're easy to service. And the fully-synchronized 265V, by eliminating double-clutching, has been a big help in easing the driver's job.

Next time you have a chance to drive a Ford truck, note these advantages for yourself. Or write us for details on how Clark's broad line of transmissions might be applied to *your* truck, tractor, bus, or other mobile vehicle.

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TRANSMISSION DIVISION
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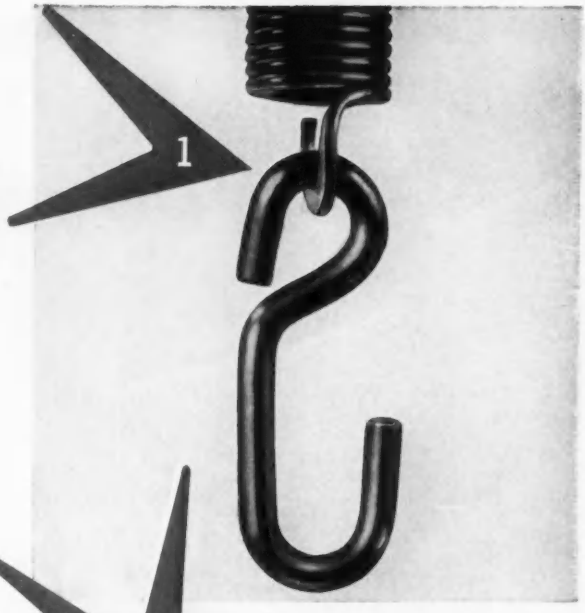
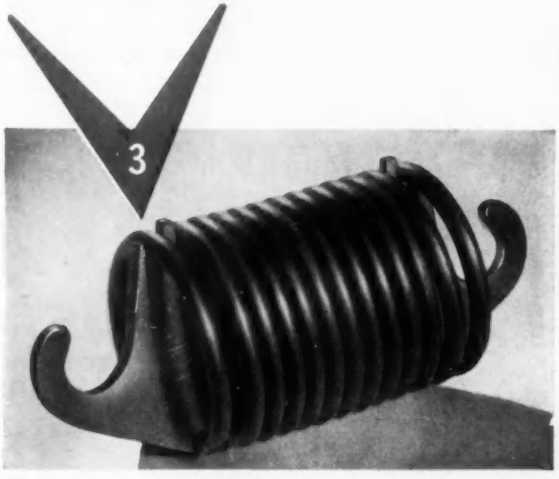
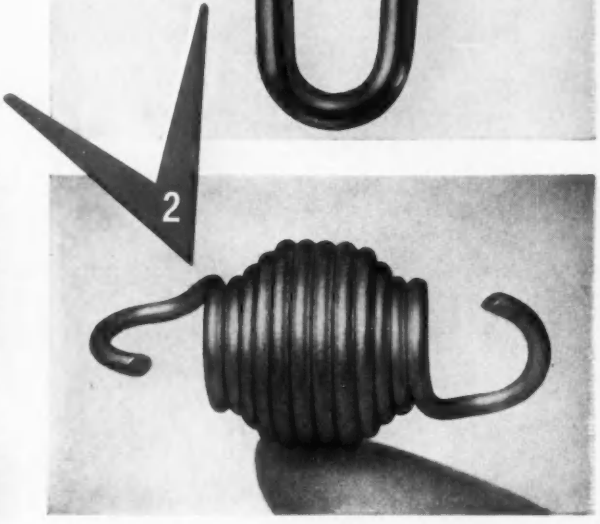
Why it pays to look at the end in the beginning







1. In this pick-arm spring for a textile machine, natural frequency vibration plus rigid end restraint caused early failure. By redesigning spring and adding swivel hook to end assembly, failure was avoided and cost reduced as well.

2. Fatigue failure caused by bending stresses occurs where end hooks join working coils. In this method of reducing the combined stress, two coils at each end are wound with a reduced diameter.

3. Another method for reducing stress concentration where end hooks join coils is to thread a flat stamping into end coils.

Here are a few examples of why it pays to call on the springmaker early in your design problems. End-hook failure of extension springs is a common occurrence that experience can help avoid. Check your specifications for performance and production economy by consulting an A.S.C. spring engineer. Write for bulletin "How to Solve Your Spring Design Problems."

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Here's where nickel steels give "Payhauler"® extra strength for hustling 27-ton loads

When this beauty roars out of the quarry with 27 tons of rock on its back, you can be sure its gears and shafts encounter brutal shock-loads and torsional stresses.

International Harvester engineers anticipated this rugged service at the design stage, took logical steps to give the "Payhauler" extra stamina:

They specified a variety of vital power-train components in heat-treated nickel alloy steels, case hardened to Rockwell "C" 60 min. for wear resistance, and at the same time providing high core properties for resistance to extreme loads, fatigue and shock.

For transmission gears, and other critical parts that take heaviest impact and compressive stresses, they chose AISI 4817 (3½% Nickel). Made from this steel, gears and pinions handle highest tooth loads, resist spalling, take impact in stride.

For components that meet all but the severest loading and abrasion, the I-H designers selected carburizing grade nickel alloy steels of the AISI 4300 series for the best combination of case and core properties. Carburized AISI 4300 steels (containing 1.85% Nickel) are used for the spiral bevel ring gear, differential pinions and side gears, transmission shafts, and integral axle and sun gear.

When you design, order, or use heavily stressed components of trucks or construction equipment, remember that nickel alloy steels take the tough jobs in stride. The new 76-page booklet, "Nickel Alloy Steels . . . in Engineering Construction Machinery" is packed with valuable engineering information. Write for a free copy. ®Reg. T.M., International Harvester Co.

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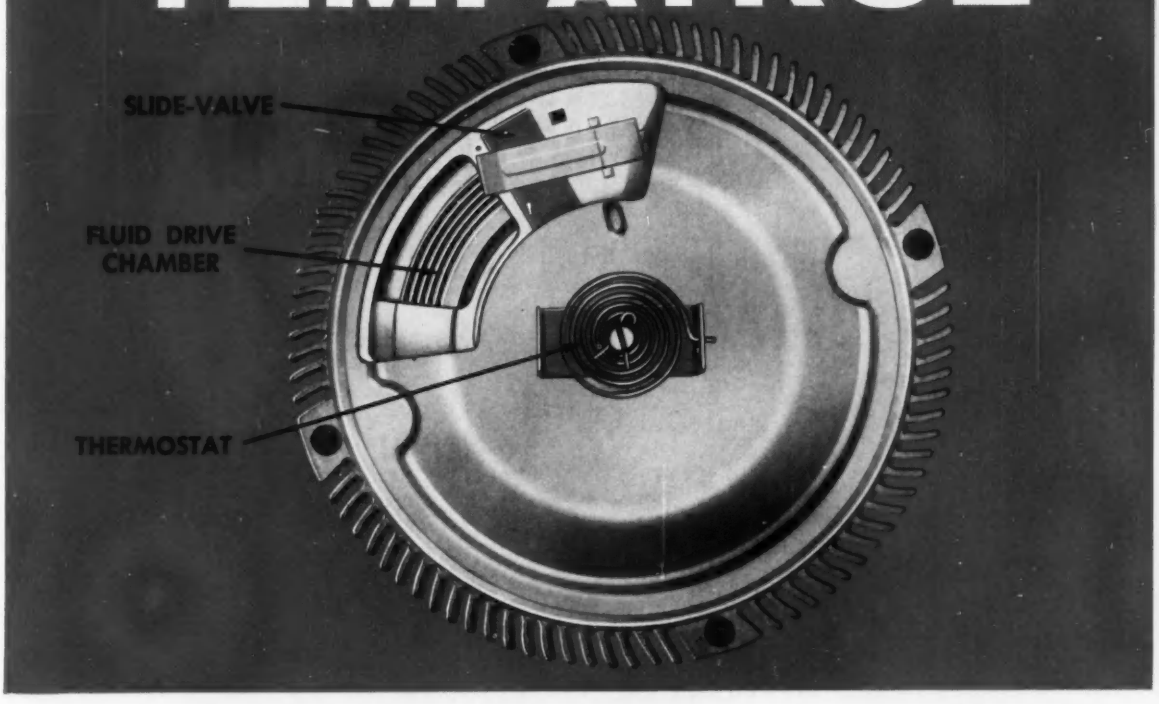
TEMPATROL



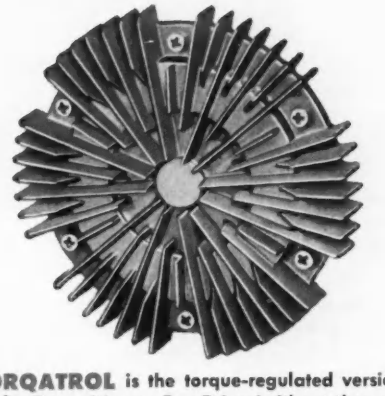
Temperature Regulated Fan Drive Increases Usable HP— Reduces Fan Noise

HOW TEMPATROL WORKS: When under-hood temperature is below the thermostat setting, slide-valve is closed; fluid-drive chamber is empty; the fan idles.

With a rise in under-hood temperature above the thermostat setting, slide-valve opens; fluid enters viscous drive chamber, increasing fan rpm to a pre-determined limit for adequate cooling.

- When cooling is not required, the thermostatic unit causes the fan to idle, thereby increasing net engine output.
- With the Tempatrol Drive engaged, adequate cooling can be achieved at low engine speeds. The top fan speed is controlled to a pre-determined maximum to avoid excessive noise.
- Operational ranges can be established to suit the requirements of each vehicle.

Eaton Tempatrol Fan Drives are readily adaptable to existing installations with only minor changes. They are now operating efficiently on leading motor vehicles. Consult with our engineers on your fan drive needs.



TORQATROL is the torque-regulated version of the Eaton Viscous Fan Drive (without thermostatic control). At low engine rpm, the fan operates at driven speeds. As engine speed increases, the viscous drive slips, limiting the maximum fan speed. Maximum fan speed limit can be raised or lowered to suit the needs of specific installations.

Tempatrol and Torqatrol are fan drive units in the family of Eaton Visco-Drives.

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The component you think "special"—and highly expensive and time-consuming to build—could well be a standard item in Rockwell-Standard's full line of driving assemblies and planetary axles, Hydra-Drives torque converters and power shift transmissions.

If your needs call for a "custom" job, you can be sure Rockwell-Standard engineers can design it to exact specifications—and build it for less. For complete information about Rockwell-Standard's full line of driving assemblies and planetary axles; Hydra-Drives torque converters and power shift transmissions, plus other components for special purpose vehicles write or call today.

Another Product of... **ROCKWELL-STANDARD CORPORATION**

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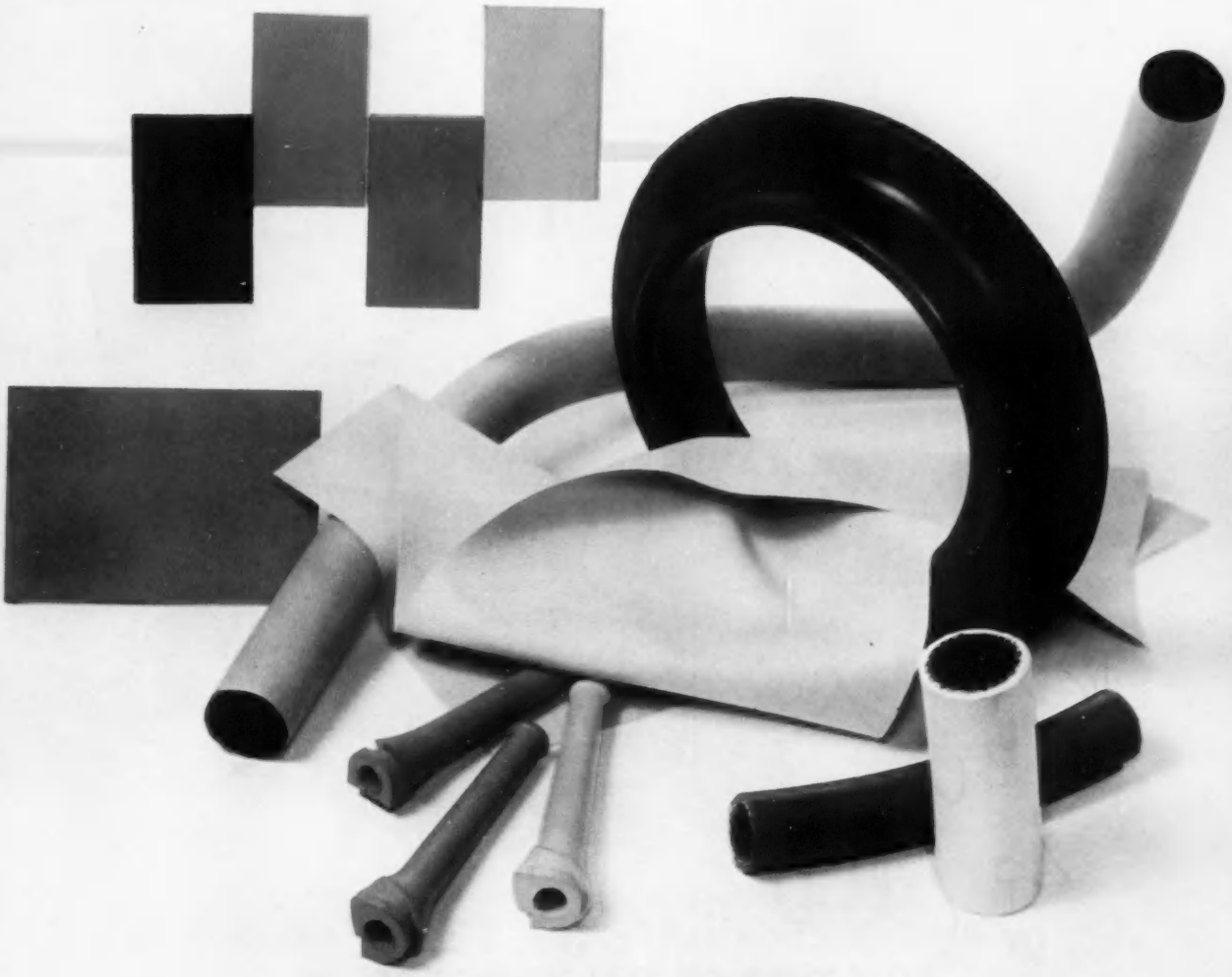
Transmission and Axle Division, Detroit 32, Michigan

Naugatuck PARACRIL OZO

THE OIL-RESISTANT, OZONE-RESISTANT NITRILE RUBBER



. . . tough, oil-proof, weather-proof and **colorful, too!**

The samples above should begin to give you some idea of the endless color possibilities in ozone-resistant rubber products made of new PARACRIL® OZO. Now you can give your product color that *sells* . . . color that identifies for coding wire and cable jacketing . . . color that blends or *contrasts* . . . color that works in a hundred ways. And you can give your product other superior properties, too.

Along with color, new weather-resistant PARACRIL OZO gives you a combination of high abrasion resistance, oil resistance, flex life and other valuable rubber properties far surpassing conventional weather-resistant rubbers.

Cast a new eye on the rubber product you make or buy. See the difference color makes. See your Naugatuck Chemical Representative or write the address below for full information on PARACRIL OZO and the advantages it offers.

Naugatuck Chemical

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DOES YOUR OIL SEAL VENDOR ACCEPT QUALITY CONTROL AS *HIS* RESPONSIBILITY?

To insure performance from their products, manufacturers constantly look for means of assurance that their purchased components are manufactured to high standards. In many cases this requires costly inspection, sorting or testing.

If you conduct such tests on Oil Seals, for example . . . How well equipped must you be? What size sample should you take? How proficient must your inspection be?

We can tell you – *in fact we can show you* . . . for IPC has pioneered the most complete, exhausting QC procedures that exist anywhere in the Oil Seal industry. Modern equipment operated by highly skilled technicians control every phase of IPC's production.

That explains increasing demand for IPC products. It also explains why our customers have fewer inspection headaches.

Why not get your next Oil Seal problem to IPC? You can rely on our "custom" approach to your problem and we will be happy to show you the elaborate QC steps that will insure the results *you* want.

IPC

OIL SEALS
PACKINGS
PRECISION MOLDING *Custom designed for your application*

INTERNATIONAL PACKINGS CORPORATION

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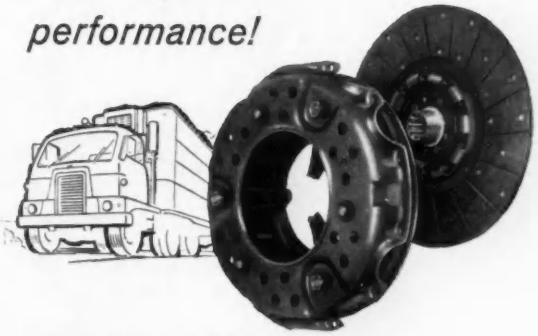
TORTURE-TEST PITS burst clutches to bits

Rockford Clutch reliability is due to the varied and frequent quality checks made at every production step. At specified intervals, clutches are removed from the production line and lowered into torture-test pits. Severe centrifugal tests spin these clutches to destruction! Each tested clutch, however, must withstand predetermined ultra-high speeds for specified time limits . . . another quality control check made to assure you of Rockford Clutch dependability. Rockford offers you an extremely wide range of proven power controls. Write today for illustrated brochure.

. . . assures you safe, enduring clutch performance!



ROCKFORD CLUTCH

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Export Sales Borg-Warner International • 36 So. Wabash, Chicago, Ill.

ROCKFORD B-W CLUTCH

DIVISION OF BORG-WARNER

WINDOW REGULATORS
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Let your imagination go! Design your power drives the way you think they should be

For, no matter what type of drive you come up with, chances are that Morse will have the equipment to implement it. And the know-how to help you perfect it!

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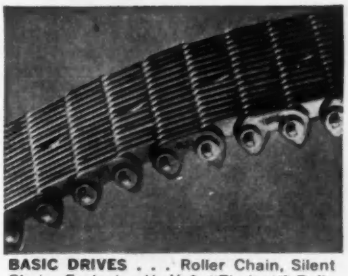

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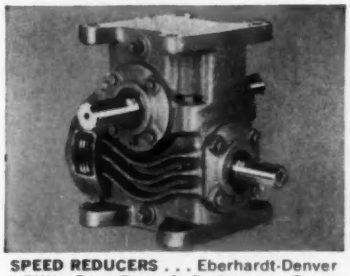
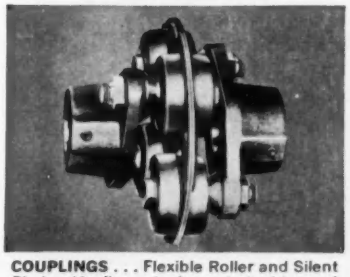


SPEED REDUCERS . . . Eberhardt-Denver "RW" PoweRgear® Reducers, Gearmotors, Conveyor Drives, Miter Boxes, Worm Gear Reducers, Helical Reducers.



COUPLINGS . . . Flexible Roller and Silent Chain, Morflex, single and double; and Morflex Radial and Marine.

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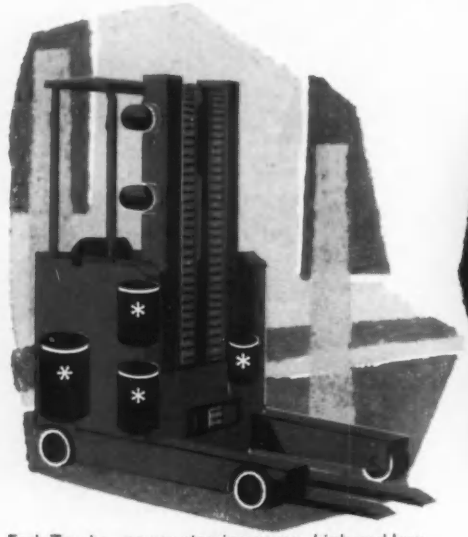
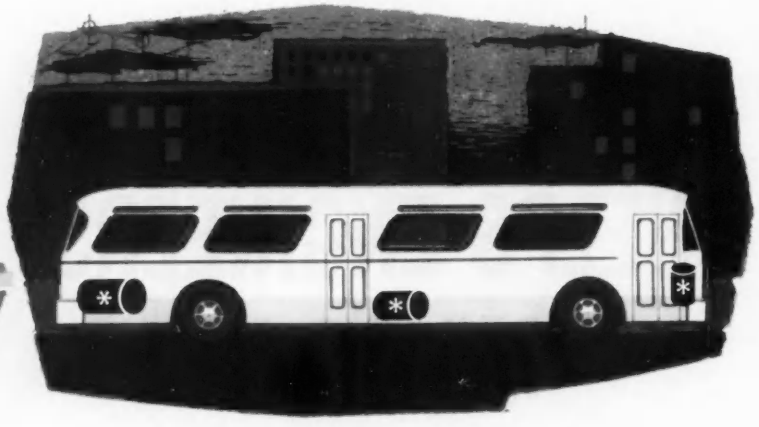


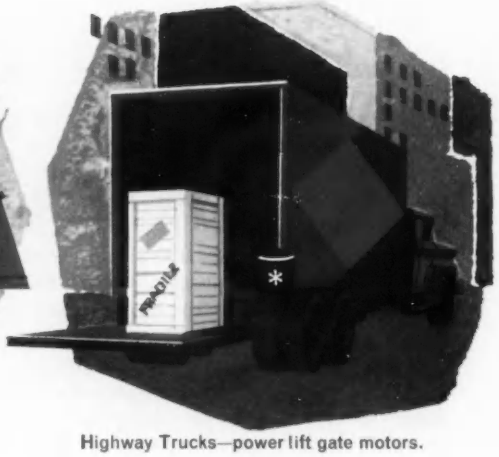
Fork Trucks—power steering pump, high and low lift pump, and propulsion motors.



Buses—heating, defrosting and air conditioning blower motors.

* electrical energy for the

Fire Trucks—siren, hose reel and pump primer motors.



Highway Trucks—power lift gate motors.

If you have a special power-motion problem, a customized Delco-Remy d.c. motor may be your answer. Like power steering pump and propulsion motors for fork-lift trucks . . . blower motors for buses . . . hoist motors for tow vehicles—and many others. Whatever it is, Delco-Remy can fit your design needs exactly! Here's why:

Delco-Remy draws on a complete stock of mass-built components to keep unit cost down. Then, using the skill and know-how of over 40 years, engineers combine components for specific torque, speed and power output requirements. Special provisions can be made, too, for extra high efficiency demands. And every Delco-Remy d.c. motor is built to pass rigid reliability standards.

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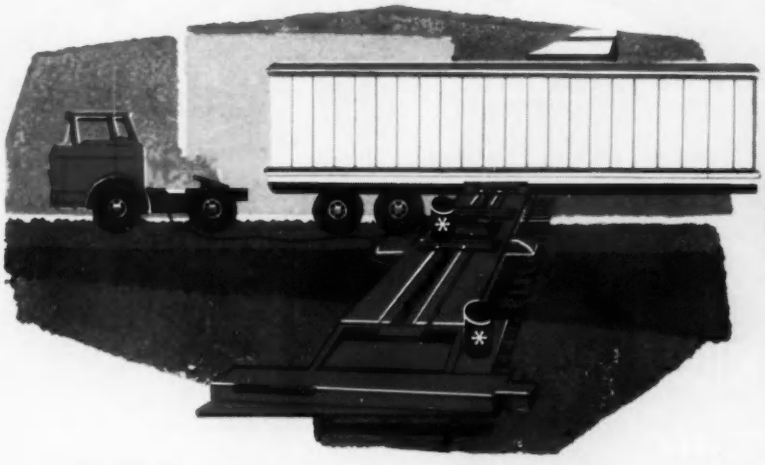
N.Y.C. R.R. Flexi-Van System—hydraulic pump motors.



Emergency Vehicles—siren motors.

special needs of power-motion

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Tow Vehicles—crane, pump and hoist motors.

Delco-Remy has built intermittent and continuous duty d.c. motors for all kinds of off-the-highway use, for high-lift trucks and low-lift pallet trucks, for buses, and police and fire equipment. Is your engineering department writing specs for a special purpose motor on your product? Or would you like to improve your present application? Be sure to consider a d.c. electric motor for your needs. Write Delco-Remy about it. We'll be happy to give you complete data and assistance.

From the highway to the stars

Delco-Remy electrical systems

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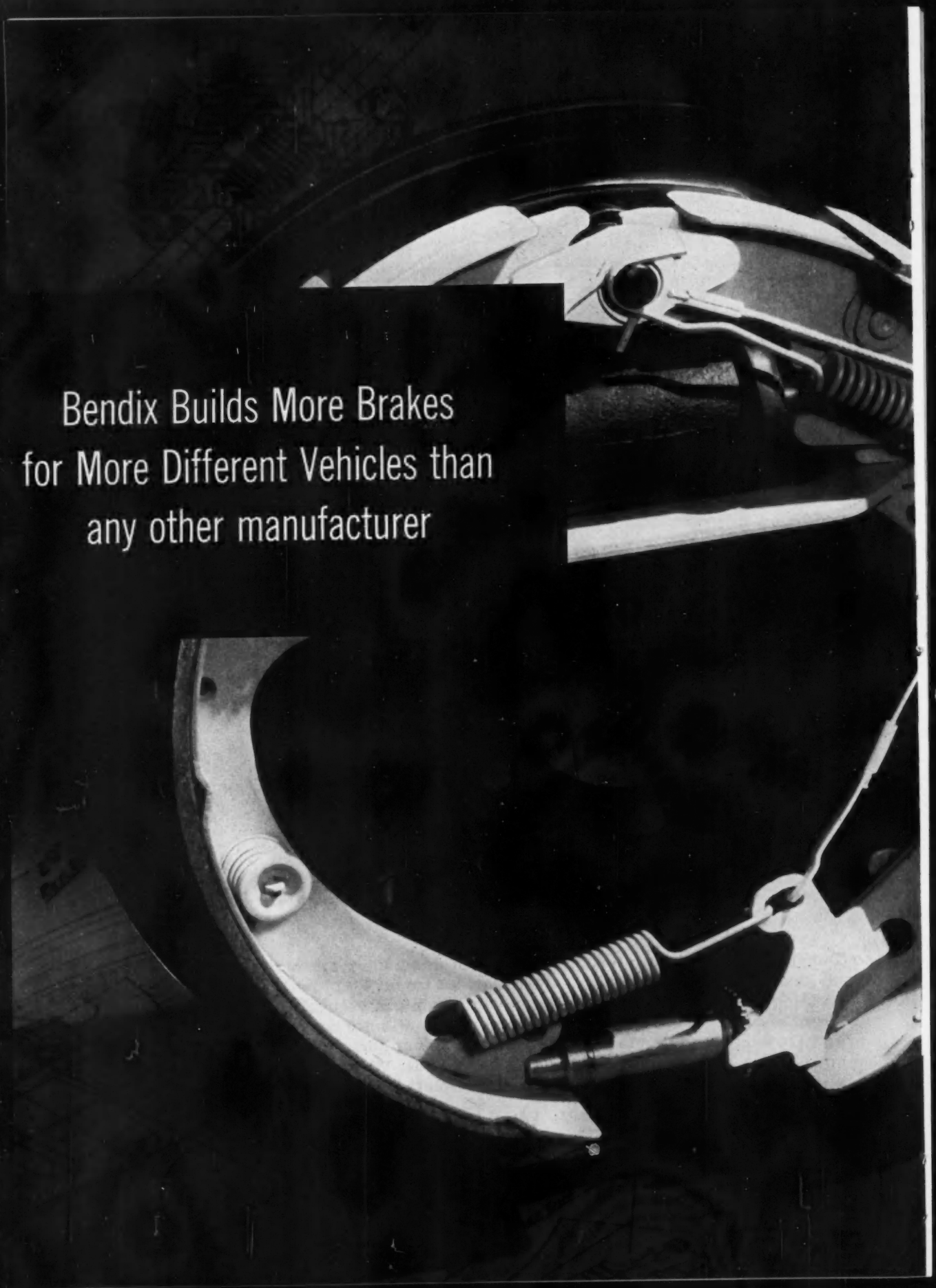
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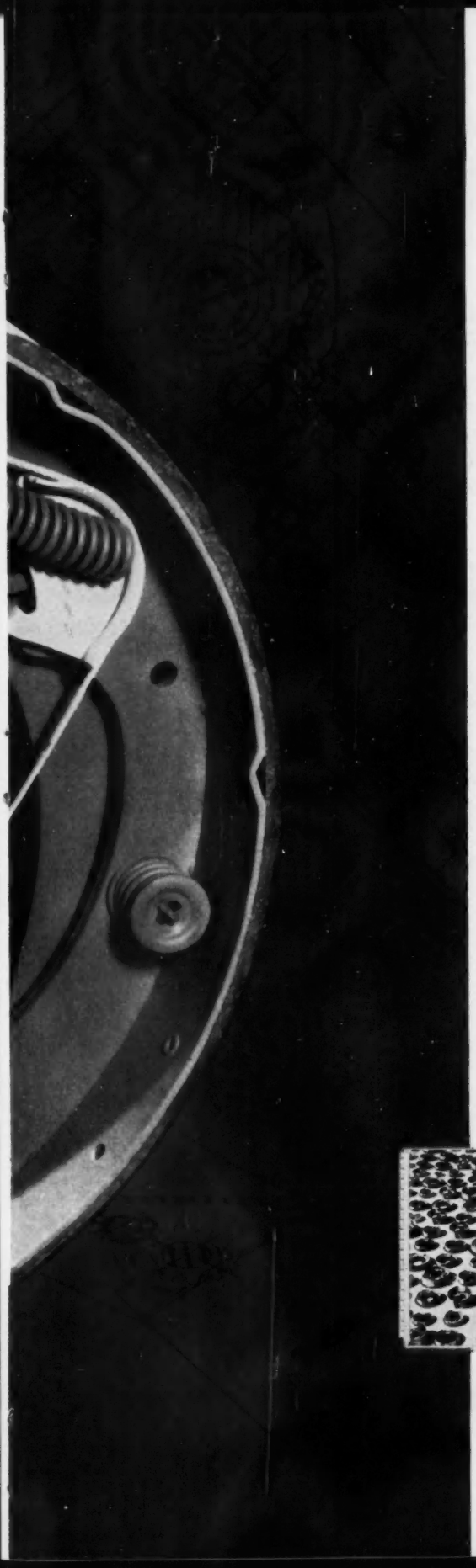

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KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many who may find it useful to review fundamentals from time to time.

Steel

for Strength
. . . Economy
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Determining the Proper Depth of Case in Alloy Steels

In one of the recent articles in this series we discussed the carburizing of alloy steels, pointing out that the purpose of carburizing is to provide a hard, abrasion-resistant outer shell or "case." Such a discussion naturally gives rise to the question, What factors influence the choice of case? Should it be shallow? Medium? Deep or extra-deep?

While it is not always wise to formulate hard-and-fast rules, the following may be used as a general yardstick:

Shallow cases (less than 0.02 in.). Suitable where wear-resistance alone is the chief requirement, and where good surface condition after heat-treating is advantageous. Not suitable if high stresses are apt to be encountered in service.

Medium cases (0.02 to 0.04 in.). For high wear-resistance. Will stand up under substantial service loads and stresses. The thickness is sufficient to permit certain finishing operations, such as light grinding.

Medium-to-deep cases (0.04 to 0.06 in.). For high wear-resistance. A case in this depth range is essential where continuing friction is involved, especially friction of an abrasive or semi-abrasive nature. It is also a good precautionary measure where application of the finished part may sometimes involve crushing action.

Extra-deep cases (more than 0.06 in.). Cases of this depth can be obtained by extending the furnace time in pack carburizing. Highly wear-resistant, extra-deep cases also withstand shock and impact. A large camshaft of an internal-combustion engine is a good example of a part requiring the extra-deep case. This is especially true of the cam lobes themselves.

If you need advice concerning case-hardened parts, let us arrange for one of our metallurgists to assist you. Bethlehem engineers are always on call, and you can depend on their recommendations. And you can depend on Bethlehem, too, when you need alloy steels; for Bethlehem makes the full range of AISI standard grades, as well as special-analysis steels and all carbon grades.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

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BETHLEHEM STEEL

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Low-cost way to reliability in weatherseals...

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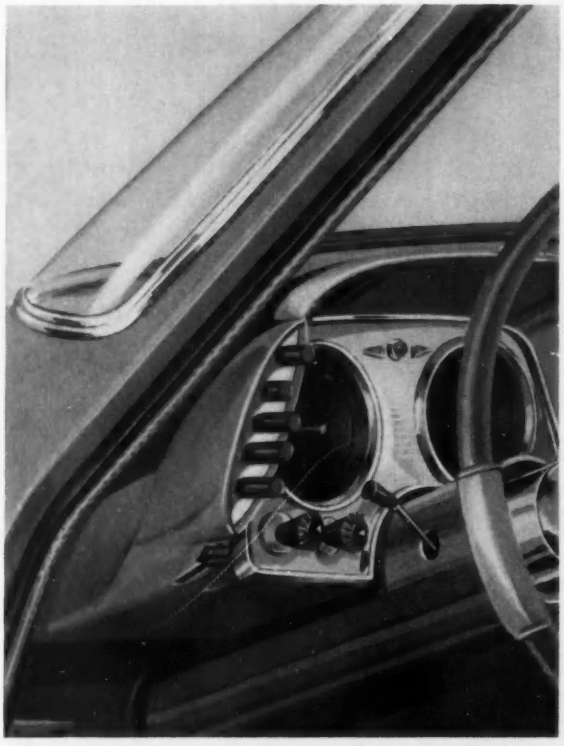
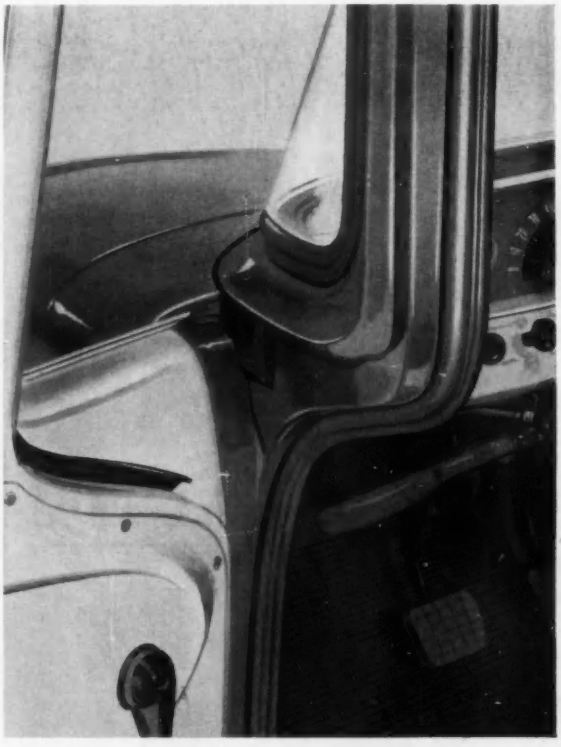
In addition, closed-cell extrusions of neoprene sponge offer you these important advantages: *new design freedom* because extruded seals permit a variety of complex cross sections including hollow bulbs; *low tooling costs* because inexpensive extrusion dies replace costly molds; *low water absorption* because their characteristic closed-cell structure virtually eliminates water penetration.

That's why manufacturers in growing numbers now specify neoprene closed-cell extrusions to prevent leakage, assure dependably weathertight seals in cars, station wagons, trucks. For information write: E. I. du Pont de Nemours & Co. (Inc.), Elastomer Chemicals Dept. SAE-5, Wilmington 98, Delaware.



Doors on this fast-selling compact are kept weathertight by a new type of weatherstripping made of extruded closed-cell neoprene sponge. Door seal and windlace are combined in a single piece, resulting in significantly lower production costs.



On this popular line of trucks, unique "self skin" of extruded neoprene sponge permits tighter radius bends to be made without wrinkling. Other applications for this new body sealing material: deck lid seals, roof rail seals, hood lacing, gaskets.

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And this mass-fabrication experience can help you. Whatever kind of small-diameter steel tubing you are now using—or plan to use—Bundy can probably make it better . . . in quantities of thousands or millions. How? By making your part from Bundyweld®, the steel tubing that's rated tops in safety in the automotive industry. Bundyweld tubing meets ASTM-254; Govt. Spec. MIL-T-3520, Type III. And by applying years of problem-solving experience to your tubing problem, Bundy engineers can often find short cuts that shave costs in mass-fabrication. Let Bundy experience help you. Write: Bundy Tubing Company, Detroit 14, Michigan.

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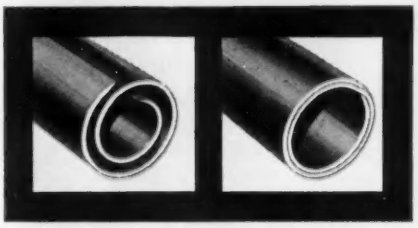

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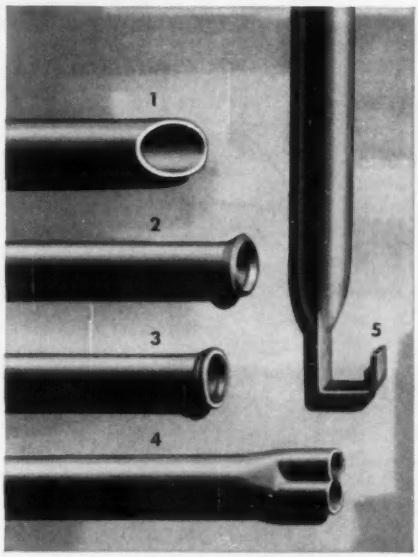

Bundy can mass-fabricate small-diameter steel tubing to solve a wide variety of design problems. The Bundyweld steel tubing shown above is: (1) sheared, (2) flared, (3) double-upset, (4) bifurcated, and (5) closed with flattened end.

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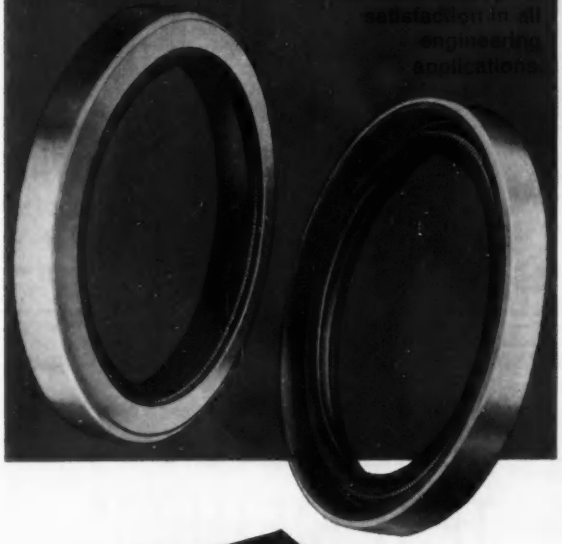

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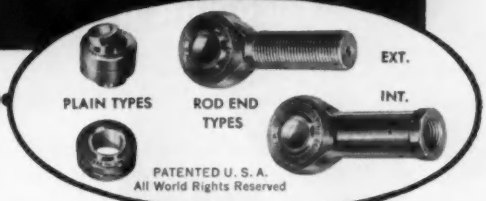

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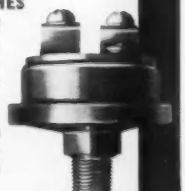

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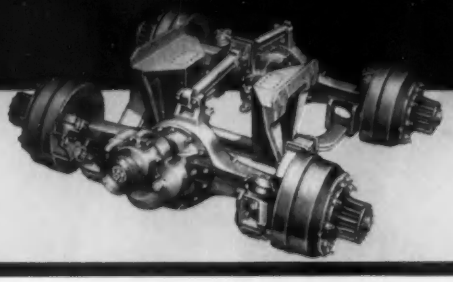

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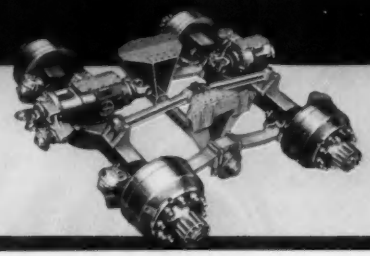

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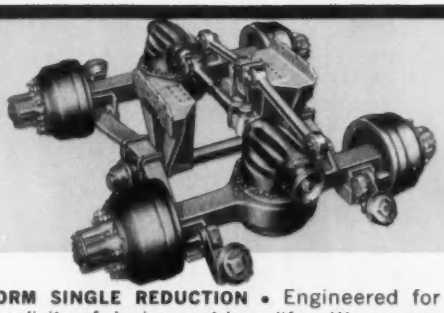

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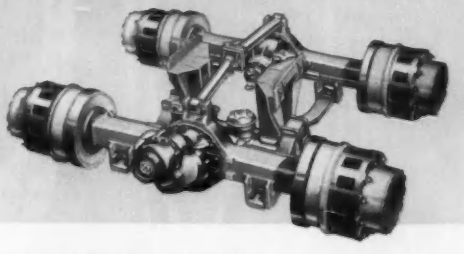

FULL PLANETARY DOUBLE REDUCTION • Engineered for extra heavy-duty operations • Planetary reduction is at wheel end for greatest mechanical advantage • Capacities up to 150,000 pounds.

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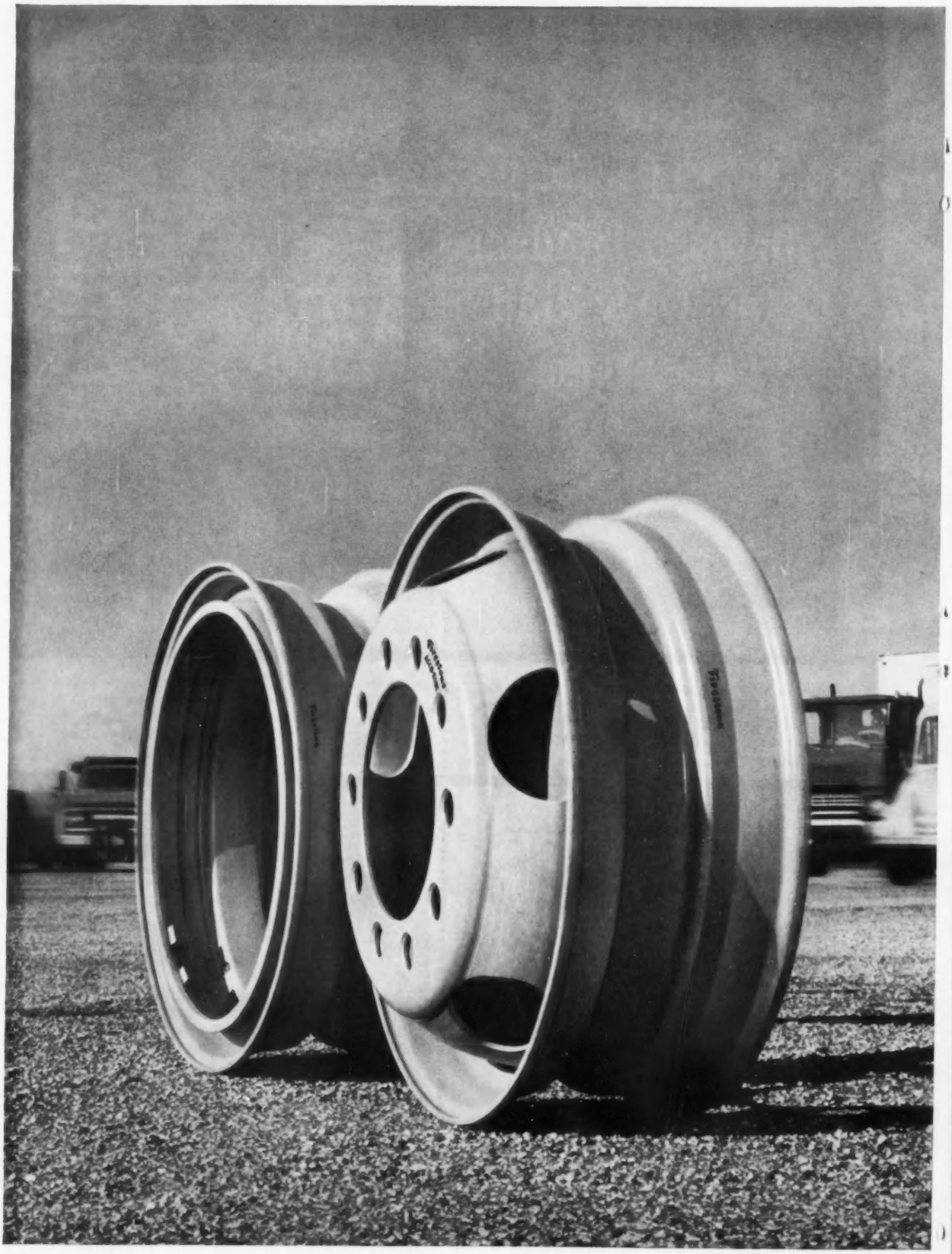

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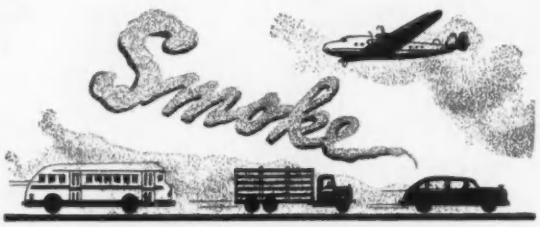

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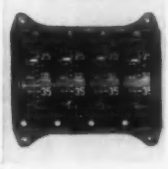

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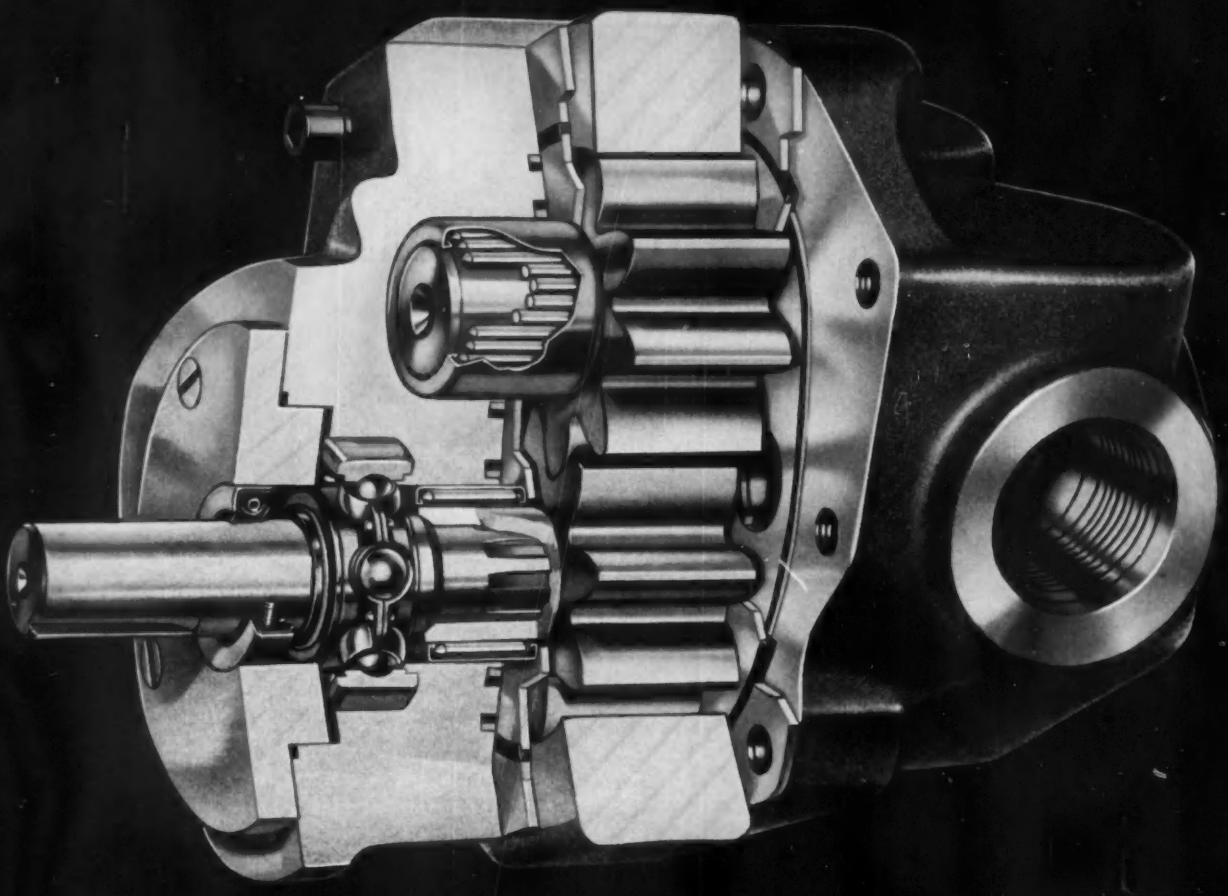

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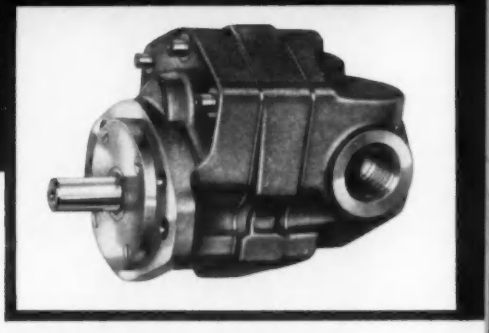

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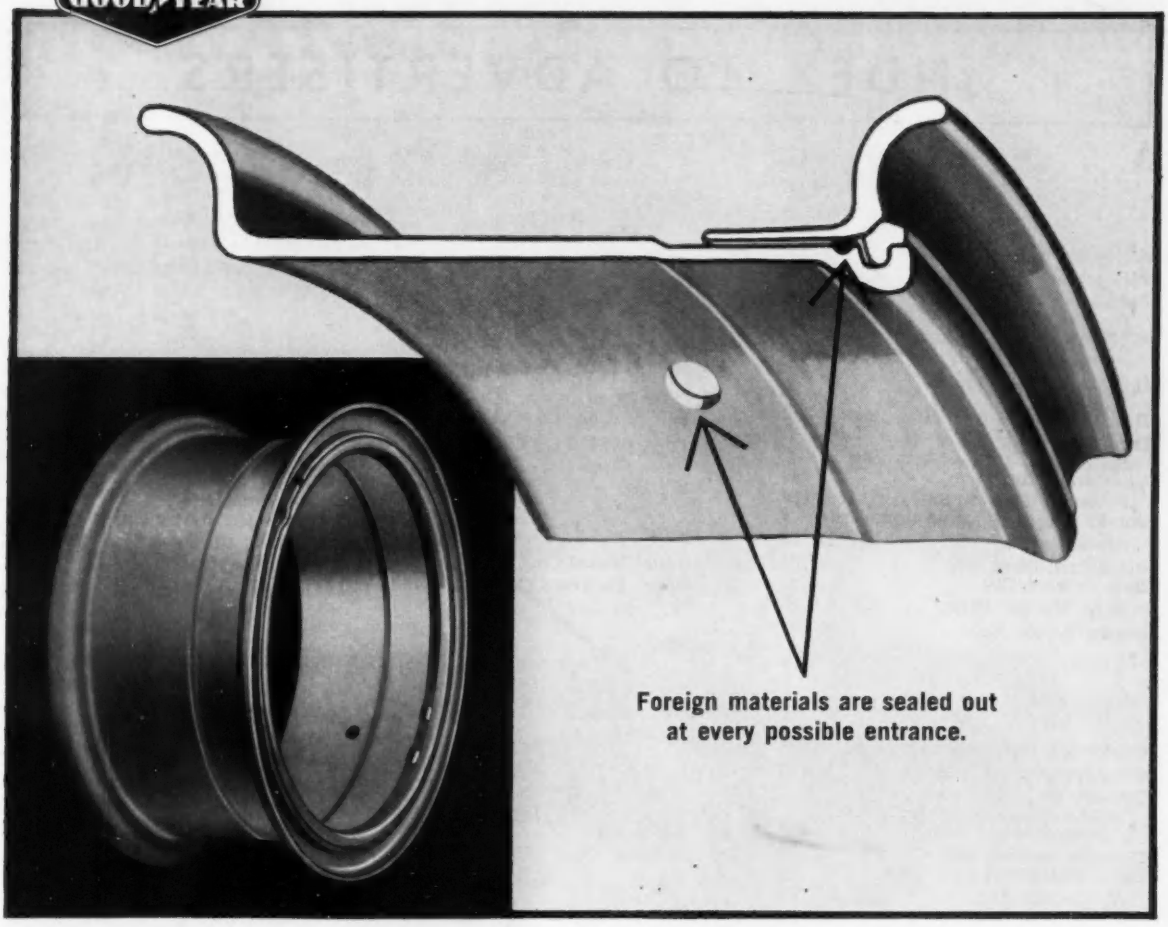

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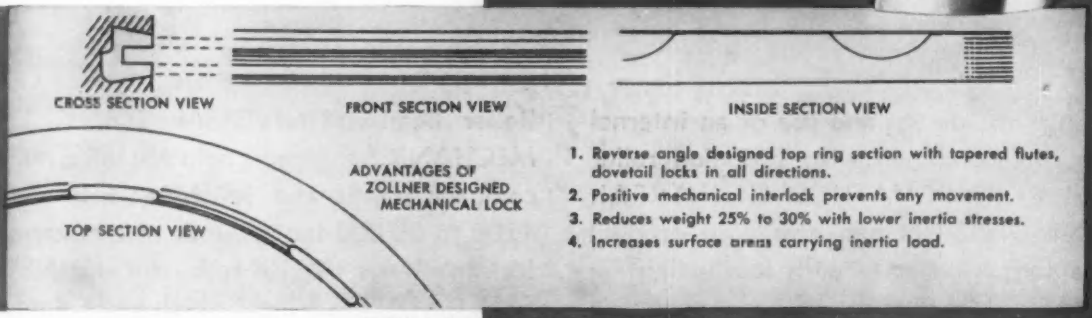

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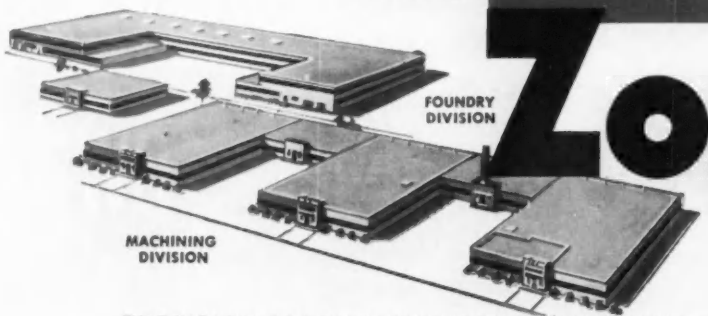

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